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THE EPIDEMIOLOGY OF TRAUMATIC BRAIN INJURY IN PENNSYLVANIA: TREATMENT AND OUTCOME DIFFERENCES BY AGE AND GEOGRAPHIC LOCATION

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ABSTRACT

Older adults tend to have poorer outcomes compared to younger adults following moderate to severe traumatic brain injury (TBI). Currently, there is a need for research focusing on how elderly TBI incidence and outcome has changed over time as the U.S. population shifts. To provide an epidemiological account of elderly TBI, the Pennsylvania Trauma Outcome Study (including data collected between 1992 and 2009) was used. The results indicated that the incidence of elderly TBI has approximately doubled in the past 18 years and that, within the elderly sample, the increase in TBI is greatest for individuals between the ages of 83 and 90. This study also demonstrated that, although elderly age independently predicted TBI incidence rates and outcomes, the geographic location of the injury is also important to consider when examining fatalities and do-not-resuscitate orders. Lastly, when comparing a number of subgroups, the results showed that elderly rural males above the age of 83 had the worst outcomes following TBI, when fatalities and functional scores at discharge were examined. Young adults in urban areas sustained the most severe injuries in Pennsylvania. Prevention and awareness of TBI in the elderly is imperative to reduce the likelihood of injury and disability. Continued statewide work is needed to demonstrate trends in elderly TBI nationwide to further add to the knowledge base used for prevention and rehabilitation work.

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DEDICATION

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Ungalukku en nanri.

Chapter 1

INTRODUCTION

Traumatic brain injury (TBI) is a global health concern and is one of the leading causes of chronic disability and death in the United States. World wide, it is estimated that 57 million individuals have sustained at least one TBI, and in the United States the approximate incidence is 1.4 to 2 million per year (Faul, Xu, Wald & Cornado, 2010, Frankowski, 1986; Langlois, Rutland-Brown, & Thomas, 2004; Moscato, Trevisan, & Willer, 1994). Comprehensive epidemiological accounts of TBI have found several consistent findings: motor vehicle accidents are the primary cause of serious injuries, men tend to sustain injuries more often than women, and when all injury severities and age groups are considered there is a trimodal distribution in injury ages that are at greatest risk for sustaining TBI (Bruns & Hauser, 2003; Whyte & Rosenthal, 1993). However, even with these epidemiological accounts further work is needed, as stated by the NIH Consensus Development Panel on Rehabilitation of Persons with Traumatic Brain Injury (1999), which recommended that epidemiological studies examining TBI risk factors and incidence rates in individuals of different age groups, gender, and race are needed. The current study focused on the need for improved descriptive work in TBI in understudied age groups and aimed to examine the epidemiology of moderate to severe TBI in individuals of older age as well as outcome differences in TBI depending on the rurality and urbanicity of the geographic injury location. This examination utilized statewide data from 1992-2009 and aims to give a comprehensive surveillance of TBI in Pennsylvania.

<u>Outcomes Following TBI</u>

The consequences of TBI can include a variety of symptoms such as physical disability, emotional disturbances, cognitive impairments, and behavioral problems (Rao & Lyketsos, 2000; Arango-Lasprilla, Rosenthal, Deluca, Komaroff, Sherer, Cifu, & Hanks, 2007; Rassovsky, Statz, Alfano, Light, Zaucha, McArthur, & Hovda, 2006; Hellawell, Taylor, & Pentland, 1999; Vogenthaler, 1987). Individuals can also experience symptoms such as headaches, fatigue, blurred vision, dizziness, and loss of hearing (Dikmen, McLean, & Temkin, 1989; Kraus & McArthur, 1996). In regard to cognitive impairments, TBI commonly leads to memory deficits, executive functioning problems, motor disabilities, and difficulties with information processing (for review see Bigler, 2001). Therefore, much of the literature examining the consequences of TBI has focused on cognition and there is a very well established literature examining cognitive dysfunction following TBI dating back to the 1950s (Meyer & Jones, 1957; Hans-Lukas & Weinstein, 1954; Spalding & Zangwill, 1950).

In addition to these cognitive sequelea, psychiatric features are among the most disabling consequences of TBI. These can occur as a direct consequence of the injury or can be exacerbated by the injury. Individuals sustaining TBI have a higher prevalence of psychiatric symptoms compared to the general population (Rogers & Read, 2007). Following TBI, common psychiatric consequences include: major depression (25%), mania (9%), anxiety disorders (11%-70%), psychosis (.7%-9.8%), apathy (10%-60%), and behavioral dyscontrol disorder (5%-70%) (Rao et al., 2000). Other work indicates that approximately 50% of individuals sustaining TBI experience a psychiatric disorder post-injury (Fann, Burington, Leonetti, Jaffe, Katon, & Thompson, 2004; Silver, Kramer, Greenwalk, & Weissman, 2001; Koponen, Taiminen, Portin, Himanen, Isoniemi, Heinonen, Hinkka, & Tenovuo, 2002).

The psychiatric and cognitive consequences following moderate to severe TBI can also significantly impact one's functional independence level. Functional limitations following TBI can include problems with independence in self care, social integration, employment, and family burden. A recent follow-up study by Wood (2008) examined approximately 3000 serious head-trauma cases and found that 52% of the individuals were moderately to severely disabled at approximately 1-year post injury. Previous work, examining functional outcomes 3 to 5 years post-injury, found that TBI resulted in impairments in multiple life domains including: the inability to work or attend school (30%), difficulties performing responsibilities at work, a reduction in the number of friends and/or less contact with family and friends (25%), and complete dependence on caregiver in an institutional setting to accomplish daily tasks (10%) (Dikmen, Machamer, Powell & Temkin, 2003). TBI often occurs during young adulthood when the consequences of the injury can have a significant impact on one's capacity for living independently, maintaining relationships, participating in leisure activities, and engaging in full-time employment (Olver, Ponsford, & Curran, 1996). These findings indicate that for many individuals, head trauma results in a significant reduction in independent functioning.

Predictors of Outcome

One of the largest literatures in the study of TBI has to do with the prediction of patient outcome (broadly defined). Within the TBI outcome literature, the most widely studied variable is the Glasgow Coma Scale (GCS) (Teasdale & Jannet, 1974). The GCS characterizes the severity of brain injury by examining eye opening, motor response, and verbal response. The severity of the injury is then deduced by the total number of points an individual receives in the three areas combined (see *Variables of Interest* section for more information on GCS scoring) with a severe TBI having a score range of 3-8, moderate TBI: 9-12, and mild TBI: 13-15. Lower GCS scores (indicating greater injury severity) have consistently been linked to short-term outcome difficulties in cognition (working memory and processing speed problems) (Goldstein & Levin, 2001), vocational status (inability to maintain premorbid or full-time employment), (Fleming, Tooth, Hassell, & Chan, 1999; Ponsford, Olver, & Curran, 1995; Stambrook, Moore, Peters, Deviaene, & Hawryluk, 1990), and functional outcome (loss of independence and self-care abilities) post-injury (Hoofien, Vakil, Gilboa, Donovick, & Barak, 2002; King, Carlier & Marion, 2005; Sherer, Struchen, Yablon, Wang, & Nick, 2008; Shores, 1989; Udekwu, Kromhout-Schiro, Vaslef, Baker, & Oller, 2004; Zafonte, Hammond, Mann, Wood, Black, & Millis, 1996).

Another widely used measure of injury severity and outcome in the TBI literature is the duration of posttraumatic amnesia (PTA). PTA is a period of time immediately following TBI in which an individual is in an acute state of confusion and disorientation (Levin, O'Donnell, & Grossman, 1979; Wilson, Evans, Emslie, Balleny, Watson, & Baddeley, 1999). Individuals in PTA are unable to remember the events that occur after their injury. PTA is considered to have resolved when continuous memory returns. Longer durations of PTA have been shown to predict poorer cognitive functioning and worsened functional outcomes (Zafonte, Mann, Millis, Black, Wood, & Hammond, 1997; McCullagh, Oucherlong, Protzner, Blair, & Feinstein, 2001; Van der Naalt, Van Zomeren, Sluiter, & Minderhoud, 1999; Brown, Malec, McClelland, Diehl, Englander, & Cifu, 2005).

In addition to the widely used measures of GCS and PTA, other variables have also been found to be associated with psychological, cognitive, and functional outcomes following TBI. For example, some demographic and clinical variables that have been linked to outcomes following TBI include: socioeconomic status and ethnic minority status (Arango-Lasprilla et al., 2007; Cameron, Purdie, Kliewer, & McClure, 2008; Dancy, Wilbur, Talashek, Bonner, & Barnes-Boyd, 2004; El-Sadr & Capps, 1992; Hoofien et al., 2002), lesion location and mechanism of injury (Bigler, 2001; Levine, Nica, Cheung, Gao, Schwartz, & Black, 2008), and premorbid intelligence and cognitive ability (Dikmen, Corrigan, Levin, Machamer, Stiers, & Weisskopf, 2009; Hanks, Rapport, Millis, & Deshpande, 1999).

Understanding outcomes and prediction of outcomes following TBI is important to help guide treatment and intervention decisions and to gain insight into risk factors for detrimental outcomes. In addition to outcome prediction research, descriptive and epidemiological studies are also critical sources of information for understanding incidence, treatment, and short-term outcome, all of which can contribute to work in awareness, education, and prevention of TBI. As Langlois et al. (2004 and 2005) noted, the collection and analysis of statewide TBI surveillance data is imperative in identifying risk and protective factors, in addition to aiding in the development of prevention strategies. Although outcome prediction research continues to be valuable for treatment purposes, prevention of TBI offers the opportunity eliminate detrimental cognitive, psychological, and functional consequences.

The Epidemiology of TBI

Improved documentation of TBI epidemiology can aid in efforts targeting the causes of TBI and further awareness, which could help reduce TBI incidence rates. However, current epidemiological accounts of TBI are difficult to compare given differences in study methods used, such as the methods used for data collection in national and statewide databases, as well as differences in inclusionary and exclusionary criteria for individuals in epidemiological databases

(Bruns & Hauser, 2003). For this reason, it is of great importance to establish more specific statewide epidemiological accounts to better tailor prevention and awareness efforts on the state-level.

Several studies have conducted statewide TBI surveillances including: an account of TBI epidemiology in individuals 65 years and older in Oklahoma from 1992 to 2003 (Fletcher, Khalid, & Mallonee, 2007), a description of fatal and nonfatal TBI cases in Wisconsin in 2001 (Tieves, Yang, & Layde, 2005), an account of TBI epidemiology in West Virginia from 1989 to 1999 (Adekoya & Majumder, 2004), and a surveillance of hospital admissions and fatal cases of TBI among Utah residents from 1990 to 1992 (Thurman, Jeppson, Burnett, Beaudoin, Rheinberger, & Sneizek, 1996). Prior epidemiological work has examined changes in head injuries in Minnesota between 1935 and 1974 (Annegers, Grabow, Kurland & Laws, 1980), head trauma characteristics in a rural area in Virginia (Jagger, Levine, Jane & Rimel, 1984), and incidence rates among the residents of San Diego, California during 1981 (Kraus, Black, Hessol, Ley, Rokaw, Sullivan, Bowers, Knowlton & Marshall, 1984). No recent study has provided a comprehensive statewide description of incidence rates, acute care variables, and injury trends, specifically focusing on older adults and urban and rural areas. Furthermore, no epidemiological study of TBI exists for the state of Pennsylvania.

More research on the epidemiology of elderly TBI is needed, in particular because the population of the United States is becoming increasingly older. Globally, the US is the 3rd most populated country. Within the US, the median age has increased over time, as has the proportion of individuals 65 years and older (Shrestha, 2006). The population growth in the elderly has not been uniform between the states or even linear over time. In the state of Pennsylvania, between the years 1992 to 2009, US Census Bureau (2010) estimates indicate a 4% increase in the

Pennsylvania elderly population; however, more recently (from 2000 to 2005) the elderly population has decreased in several states, including Pennsylvania (Colello, 2007; US Census Bureau, 2010). Given these state-wide differences, it is important to expand on the epidemiological accounts of TBI available in order to improve the knowledgebase use for prevention purposes. Furthermore, improved state-wide epidemiological accounts can help better the understanding of how injury and clinical related variables change over time and between states.

A trimodal age distribution of injury risk has been identified in the literature and indicates that children under the age of 5, individuals between the ages of 15-24, and individuals 65 years and older tend to be at the greatest risk for sustaining injuries (Bruns & Hauser, 2003; Flanagan et al., 2005; Langlois et al., 2004). In regard to mechanism of injury, motor vehicle accidents are the leading cause of TBI in the general population, accounting for about 50% of all TBIs (Drubach, Kelly, Winslow, & Flynn, 1993; Krause & McArthur, 1996; Masson, Thicoipe, Aye, Mokni, Senjean, Schmitt, Dessalles, Cazaugade, & Labadens, 2001; Polen & Friedman, 1988; Ragnarsson, 2002; Thurman, Alverson, Dunn, Guerrer, & Sniezek, 1999). Falls are the second leading cause of TBI, accounting for 20-30% of all injuries, however for individuals aged 75 years or older, falls are the most common cause of TBI. Firearms are the third leading cause of TBI (12% of all injuries). Gunshot-related, fatal TBIs are higher among men than among women and are more prevalent among African-Americans than they are among Whites (Langlois, Rutland-Brown, & Thomas, 2006; NIH Consensus Statement, 1998). In addition, alcohol plays a critical role in TBI; research indicates that alcohol intoxication is present approximately 50% of the time in patients treated for TBI (Brismar, Engstrom, & Rydberg, 1983; Edna, 1982; Gurney, Rivara, Mueller, Newell, Copass, & Jurkovich, 1992; Zink, 1993).

Research has consistently shown that males are at a higher risk for TBI than females and that this ratio of male-to-female TBI is higher in adolescence and young adulthood (Jager, Weiss, Coben, & Pepe, 2007). The high gender ratio is primarily due to motor vehicle accidents and also interpersonal violence among males. At the extremes of age, the gender ratio is more equivalent or inverted, particularly in the elderly. In regard to the most severe injuries, TBI that results from assaults and motor vehicle accidents tend to be more severe than any other mechanism of injury (Bruns & Hauser, 2003).

Etiology, incidence, and outcome from TBI are important to understand due to the fact that education, awareness, prevention and rehabilitation of TBI relies on information about these factors. However, understanding etiology, incidence, and outcome also involves an understanding of what variables can influence and change them, such as gender, age and geographic location of injury. These important demographic factors are reviewed in more detail below.

Demographic Factors of Interest Influencing TBI

Gender

Several studies have examined the influence that gender has on TBI (Colantonio, Harris, Ratcliff, Chase, Ellis, 2010; Kadyan, Mysiw, Bogner, Corrigan, Fugate & Clinchot, 2004; Liossi & Wood, 2007; Ottochian et al., 2009; Saban, Smith, Collins, & Pape, 2011). Some research indicates that females tend to sustain TBI as passengers and pedestrians while males are often injured as drivers or motorcyclists. Further, females have been shown to have a lower rate of survival from TBI (Klauber, Barrett-Conor, and Marshall, 1978; Kraus, Peek-Asa, & McArthur, 2000; Ponsford et al., 2008), as well as lower Glasgow Outcome Scale Extended scores and

Functional Independence Measure scores (Kirkness, Burr, Mitchell & Newell, 2004). A meta-analysis of TBI outcome studies revealed that outcome following TBI was worse in women than in men for 85% of examined variables (Farace & Alves, 2000).

However, there are studies in contrast to the aforementioned findings. For example, there is work showing that females have better occupational outcomes following discharge from rehabilitation than men (Grosswasser, Cohen & Karen, 1998). In addition, males have been found to have lower GCS scores and longer PTA durations compared to females; however, no gender differences have been found in long-term outcomes (Slewa-Younan, Baguley, Heriseanu & Cameron, 2007). Given the mixed results in the literature, gender continues to be a factor that is important to examine in order to further understand its relationship with TBI outcome.

Gender differences that are found may occur due to disparities in reporting the problems and difficulties following injury, variations in cognitive and psychological functioning, and also differences in brain morphology and functioning. The current study examined if gender differences exist in outcome following TBI. In addition to gender, two demographic factors that are also important to consider, which have been understudied within the TBI literature are elderly age and also population density of the area of injury (i.e., urban vs. rural injury locations). These demographic factors are reviewed in more detail below.

Age

Older age has been shown to be an independent predictor of functional outcome and fatality rate following moderate to severe TBI (Masson, Thicoipe, Mokni, Aye, & Dabadie, 2003). Although TBI-related fatality rates decreased throughout the 1990's because of a decrease in MVA related deaths and improved emergency and acute trauma services, this was not the case in all age groups sustaining TBI. For example, during this period of time there was a 21% increase in fatalities in individuals aged 75 years and older (Adekoya, Thurman, White & Webb, 2002). This risk of incidence and poor outcome is of further concern when considering population trends indicating that the aging population is continuing to increase and therefore the likelihood of sustaining TBI later in life is also increasing. It is projected that the population of individuals 65 years of age and older will reach 71 million in 2030 (US Census Bureau, 2010); representing 20% of the total US population. In 2050 the elderly population is estimated to rise to 88.5 million individuals in the US (which would be about double what the elderly population was in 2010) (Vincent & Kelkoff, 2010). The continued increase in the elderly population, along with the increased risk for TBI in the elderly, warrants the need for further research to better understand the factors associated with TBI onset in this growing population in order to help prevent injuries and detrimental outcomes.

Currently, the primary mechanism of injury for elderly individuals is falls, followed by MVA (Goldstein, Levin, Roberts, Goldman, Kalechstein, Winslow, & Goldstein, 1996; Jager et al., 2000). The annual incidence of TBI for persons aged 65 through 75 is 200 per 100,000 in the population (Kraus et al., 1984). Other sources report similar incidence rates of 150 to 200 injuries per 100,000 people among individuals 60 to 80 years of age (Cooper, Tabaddor, Hause, Shulman, Feiner & Factor, 1983).

Much research has focused on determining the differences in clinical outcome between elderly and young adult samples. For example, the elderly are less likely to be discharged home (Mckevitt et al., 2003), tend to have slower recovery rates from injury (Cifu et al., 1996), and have higher fatality rates (Cohen, Rinker, & Wilberger, 2006; Mckevitt et al., 2003; Mosenthal et al., 2002; Pennings et al., 1993). In addition, elderly individuals sustaining TBI have lower functional status scores at discharge (Cifu et al., 1996; Frankel et al., 2006; Mosenthal et al., 2002; Susman et al., 2002), increased neurobehavioral consequences from TBI (Goldstein et al., 1996), more medical complications post-injury (McKevitt et al., 2003; Pennings, Bochulis, Simons & Slazinski, 1993), and longer rehabilitation lengths of stay (Cifu et al., 1996). Increased age has also been associated with vegetative outcome following TBI (Vollmer, Torner, Eisenberg, Foulkes, Marmarou, & Marshall, 1991). The reviewed differences indicate the significant impact elderly age can have on recovery and a variety of outcomes following TBI.

There are several reasons why elderly individuals tend to have increased fatality rates and poor outcomes following TBI. Increasing age is associated with atrophy of the brain. This process increases the distance between the brain and the skull, making dural vessels more vulnerable to shearing damage, thereby creating more diffuse and detrimental injuries (Shenkin, Rivers, Deary, Starr, & Wardlaw, 2009). Increased age also makes the brain more vulnerable to subdural hemorrhages because of the natural expansion of the subdural space that occurs with the cerebral atrophy of the aging brain (Cummings and Benson, 1992). Elderly individuals also have a greater number of complications and pre-existing co-morbidities at the time of injury compared to younger adults (Perdue, Watts, Kaufman & Trask, 1998; Pennings et al., 1993).

While the incidence of TBI in younger individuals has decreased due to preventative measures (i.e. seatbelts and airbags) and greater awareness (aimed at decreasing motor vehicle accidents), TBI in the elderly population has increased, with falls being the primary mechanism of injury (Masson et al., 2001; Thurman et al., 1999). Currently, there is a need for greater research focusing on this at-risk population, including large-scale examinations of how moderate to severe TBI in the elderly has changed as the larger US population shifts.

It is unknown within the TBI literature if there are age ranges within the elderly that are more susceptible to detrimental outcomes. Within the older population in industrialized countries, about 63 percent of individuals over the age of 65 are disabled (US Department of Health and Human Services, 2000), and 20 percent have chronic disabling conditions (Freedman, Martin, and Schoeni, 2002). The onset of disability develops slowly and late life disability tends to occur following chronic illness or injury (Verbrugge and Jette 1994). The current study focuses on the elderly in different age subgroups in order to gain a more specific understanding of the relationship between older age and TBI. There has been little work in this area, although some recent work has begun to outline the trends in elderly TBI (Bouras, Stranjalis, Korfias, Adnrianakis, Pitaridis & Sakas, 2007; Fletcher, et al., 2007).

DNR Orders in the Elderly

A separate focus of this study was to examine the do-not-resuscitate (DNR) order in the growing elderly population following TBI. The elderly population is at higher risk for fatalities following TBI, and therefore it was of interest to document fatality rates, DNR orders, and predictors of fatal outcomes in the elderly.

The DNR order is a legal order that prevents the administration of CPR (cardiopulmonary resuscitation) or advanced cardiac life support (ACLS) if a patient’s heart or breathing were to stop. Since 2002 in the state of Pennsylvania, patients can secure an out-of-hospital DNR order which directs EMS personnel and treating physicians to not provide a patient CPR in the event of cardiac or respiratory arrest. There are also circumstances under which an appropriate representative of a person who issued a living will is able to secure an out-of-hospital DNR order for a patient (Pennsylvania Department of Health, 2012). If CPR is judged to be medically futile, then a physician can also opt to discontinue this intervention. The goal of the DNR order is to prevent patients from undergoing an intervention to treat a medical event that, if successfully treated, would ultimately leave the individual with substantial neurologic impairment or poor quality of life (Choudhry, Choudhry & Singer, 2003; Ehlenbach, Barnato, Curtis, Kreuter, Koepsell, Deyo & Stapleton, 2009; Zoch, Desbiens, DeStefano, Steuland & Layde, 2000).

The DNR order has been increasing in all individuals, including the elderly, over the past several decades (Berlowitz, Wilking, & Moskowitz, 1991; Evans & Brody, 1985; Finucane & Denman, 1989; Gleeson & Wise, 1990; Kellogg & Ramos, 1995; Terry & Sweig, 1994). Prior research has established that increasing age is associated with greater DNR rates in medical populations (Bedell, Pelle, Maher & Clearly, 1996; Shepardson, Younger, Speroff, O'Brien, Smyth & Rosenthal, 1997; Younger, Lewandowski, McClish, Juknialis, Coulton, & Bartlett, 1985; Zimmerman, Knaus, Sharpe, Anderson, Draper, & Wagner, 1986). Although age has been associated with increased frequency of the DNR order, it is unknown what pre-hospital factors and TBI-related clinical variables may contribute to DNR orders (such as time to arrive to emergency department and initial GCS score) and also what changes have occurred in the frequency of DNR orders following TBI over time as the aging population has increased.

This examination will help to determine how incidence rates, important pre-hospital variables, and outcome variables in TBI have changed in the elderly and elderly subgroups in the hope of better informing further public health work in prevention and awareness. As previously noted, in addition to examining TBI in the elderly, this study aimed to examine another understudied variable that is important in understanding epidemiology and outcome following

TBI—the geographic location of injury. Below is a review of TBI in rural and urban communities.

Influence of Geographic Location of Injury

About 21% of the US population resides in rural areas and several studies have found that the death rate from neurotrauma is disproportionately higher in these areas (Baker, Whitfield, & O'Neill, 1987; Peek-Asa, Zwerling, & Stallones, 2004). Although a number of studies have examined TBI in rural and urban areas, none have examined how the geographic location of the injury may influence the etiology of TBI and outcome from injury in older age groups. Below is a review of the TBI literature that has examined the differences between rural and urban injuries.

Rural vs. Urban Injuries

Several key differences between rural and urban injuries have been established in the TBI literature. For example, fatality rates, incidence rates, and mechanisms of injury have been found to differ depending on rural or urban injury locations. Fatality rates have been shown to increase with the rurality of the injury location (Gavella, Hoffman, Marine, and Stallones, 1997). Later work has also found that decreasing county population density is the strongest predictor of trauma death rates in the United States (Eberhardt, Ingram, Makuc, Pamuk, Freid, Harper, Schoenborn, & Xia, 2001; Institute of Medicine, 1999).

In regard to mechanism of injury, the primary mechanism of injury for TBI is motor vehicle accidents (MVA), irrespective of geographic location or population density. However, MVA trauma victims in rural areas are more likely to be under the influence of alcohol and less likely to use safety restraints, such as seatbelts or child seats, compared to individuals sustaining injuries in urban areas (Peek-Asa, Zwerling & Stallones, 2004). Another difference in mechanism of injury is that pedestrian injuries are lower and agricultural accidents and occupational injuries are higher in rural areas compared to urban injury locations (Mueller, Rivara, & Bergman, 1988). Further, injuries resulting from violence and suicide occur at a lower frequency in rural areas compared to urban areas (Durhart, 2000; Peek-Asa et al., 2004).

Differences in fatality rates have also been found depending on mechanism of injury. For example, although pedestrian injuries happen less frequently in rural areas compared to urban areas, pedestrian fatality rates are higher in rural locations, even when controlling for age and speed of vehicle (Mueller et al., 1988). In addition, data from the National Highway Traffic Safety Administration (2001) indicate that rural MVAs account for 61% of all traffic fatalities and show that the rural–urban fatality difference is increasing over time. Several statewide analyses of motor vehicle crashes have shown that fatality rates in the most rural counties are almost double those observed in urban counties (Muelleman & Mueller, 1996; Maio, Green, Becker, Burney, & Compton, 1992). The higher fatality rates for the reviewed mechanisms of injury may be due to greater injury severity in rural areas compared to urban areas (Chapital, Harrigan, Davis, Easa, Withy, Yu, & Takanishi, 2007). In addition to differences in mechanisms of injury, fatality rates, and injury severity, there are also differences in transportation time to a trauma center depending on the geographic location of the injury.

It is estimated that 69.2% and 84.1% of all US residents have access to a level I or II trauma center within 45 and 60 minutes, respectively. However, 46.7 million Americans in rural areas do not live within an hour of a trauma center, whereas 42.8 million Americans in urban areas have access to 20 or more level I or II trauma centers within an hour, thereby limiting the ability for individuals in rural areas to receive expedient trauma care (Branas et al., 2005). The overall number of trauma centers in the US has increased in the last decade; however, their geographic distribution varies nationwide and many individuals are not within timely access to trauma centers, which has been shown to affect survival rates from injury (Bass, Gainer, & Carlini, 1999; Esposito et al., 1999; MacKenzie, Hoyt, Sacra, Jukovich, Carlini, Teitelbaum & Teter, 2003). Some challenges that trauma systems have in rural areas that impede efficient care and support of patients include: longer distances required for emergency medical service personnel to reach injured individuals and to reach advanced trauma care facilities, the predominance of volunteer emergency medical service providers (who may have less advanced training), and the lack of efficient protocols for triage and transfer decisions (Grossman, Kim, Macdonald, Klein, and Maier, 1997).

Given the differences established in mechanism, fatality rate, and trauma care time depending on geographic location of injury, several studies have examined differences in functional outcome following injuries in urban and rural areas. Individuals sustaining injuries in rural areas tend to be more functionally dependent, have more health complications post-injury (Schootman & Fuortes, 1999), and have more vocational difficulties (Johnstone, Price, Bounds, Schopp, Schootman, & Schumate, 2003). Differences in functional outcome in urban and rural areas may be due to differences in rehabilitation and support services (Johnstone, Nossaman, Sckopp, Holmquist, & Ruprigkt, 2002). Therefore, environmental barriers impact treatment and outcomes for individuals sustaining TBI, particularly in rural areas where trauma centers and rehabilitation resources are scarce.

There remains little work examining urban and rural injuries in the elderly population. More specifically, it is unknown how elderly trauma care (i.e. transportation time, recovery rates) has changed or improved over time in urban and rural areas following TBI as research on disparities in trauma center care has increased and also the number of trauma centers nationwide (and in the state of Pennsylvania) has increased. Older age is associated with differential outcome, mechanism, and recovery following TBI; however, it is currently unknown if the relationship between trauma care and outcome also differs in the elderly. This study aimed to examine trauma care variables, specifically in the elderly in urban and rural injury locations.

The Current Study

Moderate to severe traumatic brain injury is a leading cause of death and disability in the United States, but the epidemiology of these injuries in older adults has not been extensively examined, especially on a statewide basis. It has been established that elderly individuals fare worse following TBI compared to younger adults. What remains unknown is how pre-hospital related variables have changed over time and further, what disparities exist in these variables by gender, age, and geographic location. It is also unknown how pre-hospital variables ultimately influence outcomes; specifically, DNR orders, fatalities, and functional outcomes. Although there has been work examining the relationship between geographic location of injury, fatality rates and functional outcomes, there has been relatively little work done in this area among older adults. The current study aims to provide a comprehensive epidemiological account of TBI in Pennsylvania during the years of 1992 to 2009, specifically focusing on TBI outcomes in older age and in urban and rural locations.

Examining trends and outcomes in TBI by age and geographic location is important in the state of Pennsylvania as it is a good representation of nationwide population estimates in elderly groups and urban and rural populations. For example, although recently there has been evidence of a decrease in the Pennsylvania population, US Census Bureau data indicates that from 2000 to 2010, all states except Rhode Island had an increase in elderly population. Pennsylvania also had the fourth greatest share of the US population that was 65 years and over in 2010. Thus, nationwide long-term population trends in elderly growth are also represented in Pennsylvania, and there is a relatively large sample size in the state which may make results more generalizable. Furthermore, in 2010 nationwide US Census Bureau estimates indicated that 81% of the total US population lived in Urban areas, compared to 19.3% in Rural. The state of Pennsylvania has 48 rural counties and 19 urban counties; in 2010, 27 percent of the state's population lived in a rural county, and 73% in urban (The Center for Rural Pennsylvania, 2012). Thus, Pennsylvania has a similar breakdown of urban and rural residents, although a greater percentage of individuals in rural areas. The current study examined the incidence, etiology, and natural history of TBI in the state of Pennsylvania.

Aims and Hypotheses

Aim 1) To provide a current statewide epidemiological surveillance of TBI incidence, treatment, and short-term outcome in the elderly. This description will focus on mechanism of injury, age, gender, injury severity, pre-hospital treatment, fatality rate, and functional outcome.

Aim 2) To determine the changing risk for TBI in the elderly, and elderly subgroups, over time (i.e. incidence rates, fatality, and functional outcome).

Hypothesis 1a: It is anticipated that the incidence of elderly TBI in Pennsylvania will increase and this increase will remain after controlling for population growth.

Hypothesis 1b: Increased age will pose a higher risk for detrimental outcomes (lower FIM scores, higher fatality rates) following TBI.

Aim 3) To establish the influence of age on rates of DNR orders.

Hypothesis 2: Frequency of the DNR order will increase with age of injury across three elderly age groups. Therefore, the oldest elderly individuals will have a higher rate of DNR orders compared to other elderly age groups.

Aim 4) To examine if pre-hospital trauma care predicts the frequency of DNR orders in the elderly.

Hypothesis 3: Elderly individuals with greater injury severity and longer transport times to the hospital will have a higher frequency of DNR orders when compared to younger adults with severe injuries and longer transport times.

Aim 5) To examine if geographic location predicts differences in injury variables and outcome.

Hypothesis 4: When compared to urban elderly and rural young adults, elderly individuals in rural counties will sustain more severe injuries, have longer transportation times, slower recovery rates, higher fatality rates, and a higher probability of positive DNR orders

Aim 6) To examine if geographic location predicts changes in injury severity and fatality rate over time.

Hypothesis 5: Fatality rates should decrease overtime in both rural and urban areas, however this decrease will be greater in urban areas. It is hypothesized that injury severity scores will decrease (higher mean GCS scores) over time in urban areas compared to rural areas where injury severity will increase (lower mean GCS scores) over time. Therefore, it is anticipated that in rural areas the fatality rate will decrease, however elderly individuals will be surviving with more severe injuries overtime.

Aim 7) To examine changes in transport time in rural and urban counties over time and the implications for fatality rates and functional outcome in the elderly.

Hypothesis 6: It is hypothesized that transport time will decrease over time in both urban and rural areas and that differences in transport time should predict FIM scores and fatal *injuries.*

Aim 8) To determine the group with the most severe injuries and poorest outcomes following moderate-severe TBI

Hypothesis 7: The group that sustains the most severe injury and has the poorest TBI outcomes (high fatality rates and low functional scores at discharge) will be older elderly females sustaining injuries in rural counties.

Chapter 2

METHODS

The current study used statewide data, collected between the years of 1992 to 2009 from the Pennsylvania Trauma Outcome Study (PTOS), a statewide trauma registry formed by the Pennsylvania Trauma Systems Foundation (PTSF) in Mechanicsburg, PA. The PTSF database was created in 1985 and its mandate was established with the creation of the Emergency Medical Service Act (Act 45) in July, 1985. Trauma patients are only included in this database if they were seen at a PTSF accredited trauma center; therefore, individuals receiving treatment from non-trauma centers are not included. The PTSF accredits trauma centers by following guidelines defined by the American College of Surgeons. Pennsylvania hospitals can apply to the PTSF and a governing body/committee determines if the applicant hospital meets the Standards for Trauma Center Accreditation. Trauma centers that are accredited by the PTSF are mandated to report the data elements to the PTOS (see below for further details), and their continued accreditation depends on compliance with this standard.

Currently, there are 31 active, accredited trauma centers in the state of Pennsylvania, which represent centers in both rural and urban counties. Of those 31 centers, 22 have been accredited and present in the PTOS for every year from 1992 to 2009. See Table 1 for current participating trauma centers.

Table 1. Accredited PTSF Trauma Centers

1. Abington Memorial Hospital	17. Paoli Hospital
2. Albert Einstein Medical Center	18. Penn State Milton S. Hershey
3. Allegheny General Hospital	19. Pocono Medical Center
4. Altoona Hospital	20. The Reading Hospital & Medical Center
5. Aria Health - Torresdale Campus	21. Robert Packer Hospital
6. The Children's Hospital of Philadelphia	22. St. Christopher's Hospital for Children
7. The Children's Hospital of Pittsburgh	23. St. Luke's Hospital
8. Community Medical Center	24. St. Mary Medical Center
9. Conemaugh Memorial Medical Center	25. Temple University Hospital
10. Crozer-Chester Medical Center	26. Thomas Jefferson University Hospital
11. Geisinger Medical Center	27. UPHS University of Pennsylvania Medical Center
12. Geisinger Wyoming Valley Medical Center	28. UPMC Mercy
13. Hahnemann University Hospital	29. UPMC Northwest
14. Hamot Medical Center	30. UPMC Presbyterian
15. Lancaster General Hospital	31. York Hospital
16. Lehigh Valley Health Network Cedar Crest	

PTSF Database

Procedures for data extraction have remained consistent for the PTSF since 1985. Each trauma center registrar is responsible for the quality and accuracy of data entered by their facility. However, the PTSF has established methods to ensure the quality of the data, for example, by maintaining uniform statewide data definitions and by conducting regular registry audits of the trauma centers. Data is integrated from trauma centers on a quarterly basis. Although data is submitted to the PTSF on a daily basis, the foundation processes the data during the 3 month period by rechecking, assessing, and correcting data as needed. Once the data has gone through the PTSF submission processing it is integrated into the main database.

Inclusionary criteria for individuals in this database included a diagnosis of trauma (ICD-9-CM injury codes 800-999) and one of the following criteria: admission to any Intensive Care Unit (ICU), admission to a step-down unit, all trauma diagnosed deaths, all trauma patients remaining in a hospital facility for over 48 hours following Emergency Department admission, all transfers seen at another facility (unless transferred to ER and then discharged home), and individuals transferred out to another facility. For the purposes of this study, individuals were selected with ICD-9-CM codes indicative of TBI, and the current database included ICD-9-CM codes 800-997 and total GCS scores indicating moderate to severe TBI (3-12)

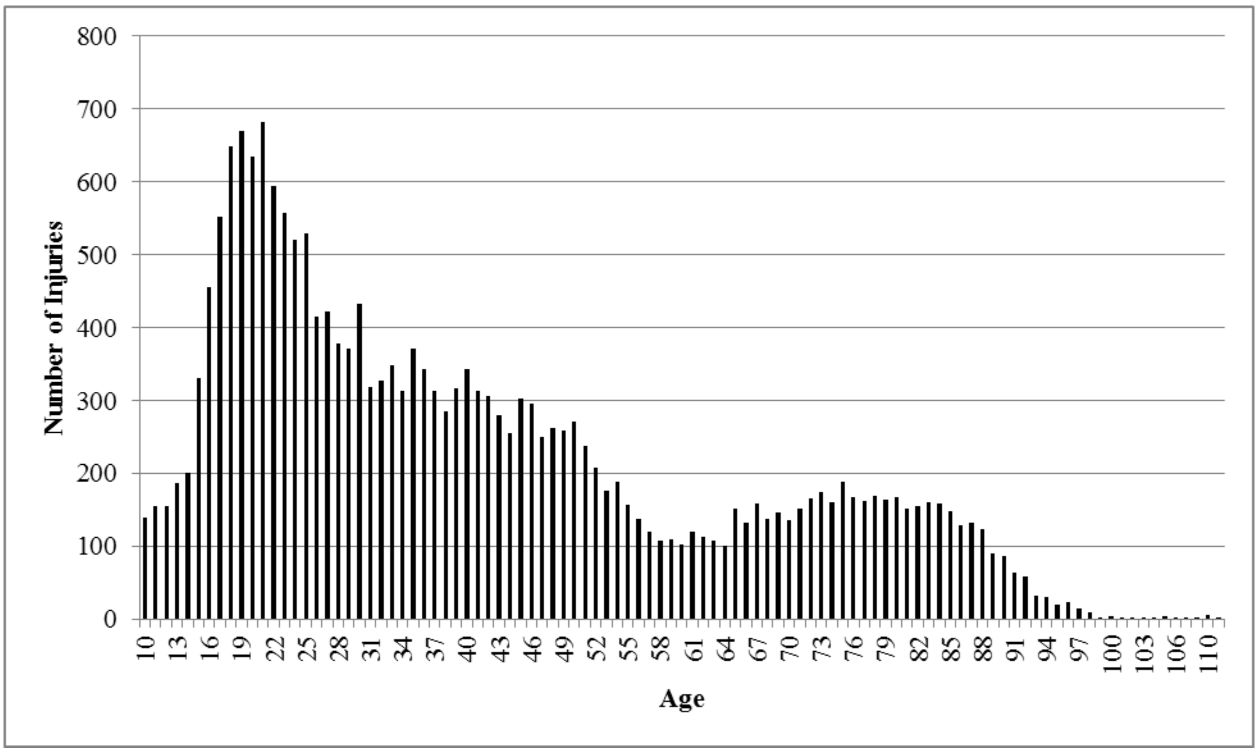
The information collected for the PTOS by the PTSF includes over 200 variables regarding fatal and non-fatal cases of TBI. See the *Variables of Interest* section for information on the variables focused on for the current examination. The only identifying information provided in the database was date of birth and gender; further identifying information such as name, address, telephone number and social security number are excluded to protect patient confidentiality.

Study Design

The current study examined TBI in the elderly and also in urban and rural areas. Based upon frequency distributions of age-related peaks of TBI incidence, the elderly sample was defined as individuals 65-90, see Figure 1. Further, in order to examine elderly age subgroups, 3 separate elderly groups were formed as follows, in order to create equal sample sizes and groups with equivalent year ranges: Younger Elderly (YE) group--ages of 65 through 73, Middle

Elderly (ME) group--ages 74 to 82 years of age, and Older Elderly group (OE) group--ages of 83 to 90. In addition, a young adult group was defined as ages 15-25 (based upon frequency distributions of age-related peaks of incidence seen in Figure 1). The variables examined in these age groups are described in more detail below.

Figure 1. Frequency Distribution of Age-Related Peaks of Incidence.



Another goal of this study was to examine how elderly TBI differs in rural and urban injury counties. Rural and urban definitions from The Center for Rural Pennsylvania were used in the current study. The Center for Rural Pennsylvania is an agency formed by the Commonwealth of Pennsylvania and is the governing body that determines what counties in the state are rural versus urban. The population of Pennsylvania is 12,702,379 and the number of square miles of land is 44,743; therefore, the population density is 284 persons per square mile. The definition used by the Center for Rural Pennsylvania is that any county with a population density of less than 284 is considered rural, and anything above this is considered to be an urban county. There are 67 counties in the state of Pennsylvania, and 49 are considered Rural while 18 are Urban. See Appendix A for the population density for each county in Pennsylvania, along with their rural or urban designations that were used for the current study.

Data Extraction

Data were obtained from the PTSF in Excel file formats. The full database contains over 200 variables at various points during injury, hospital stay, and discharge for individuals of all ages sustaining mild to severe TBI in the state of Pennsylvania. Separate documents provided by the PTSF contained detailed descriptions of each variable in the database, as well as the coding system for each variable. Prior to selecting the variables of interest, individuals with mild TBI were eliminated from the full database. Following this, the variables of interest for the current study (see below for more details) were selected and copied into SPSS Statistics version 19. Within SPSS, the variables were defined and labeled according to the coding systems provided by the PTSF. Within each variable, any blank cells or cells labeled as “not available” or “unknown” were coded as missing data.

Variables of Interest

Mechanism of Injury

Within the PTSF database, the mechanism of injury was indicated by ICD-9 E-codes. Although there are over 25 categories of E-codes representing various mechanisms of injury, the following E-codes were recoded into SPSS and used in the current study as they represent the most frequent mechanism of injuries in the PTSF database: Railway accidents (e800-e807), motor vehicle traffic accidents (e810-e819), motor vehicle non-traffic accidents (e820-e825), other road vehicle accidents (e826-e829), accidental falls (e880-e888), suicide and self-inflicted injury (e950-e959), homicide and injury purposely inflicted by other persons (e960-e969), and crushing injury (e925-929). Other E-code mechanisms of injury, either not represented in the PTSF database or represented in less than 1% of the study sample include: water transport accidents (e830-e838), air and space transport accidents (e840-e845), and injury resulting from operations of war (e990-e999).

Injury Severity

Injury severity was measured using the Glasgow Coma Scale score. As noted above, individuals were selected from the PTSF database with total GCS scores, at the scene of injury, of 3-12, indicating a moderate to severe TBI. See Appendix B for a description of the scores in each category of the GCS (eye opening, verbal response, motor response).

Within the PTSF database, GCS scores are documented at several time points acutely and during hospital stay. For the current study, GCS scores from the following two time points were used to examine GCS change following TBI: at the scene of injury--this is the initial assessment and earliest documented vital signs of the injured individual by emergency medical services personnel, and at emergency department admission (or initial admission to hospital if patient is a direct admit and bypasses the emergency department).

Fatality Rate

The PTSF database provides information on whether a patient was living or deceased at the time of hospital discharge. Fatality rates were determined using this variable; however, when a patient died (i.e. at the scene of injury or during hospital stay) is unknown.

Do Not Resuscitate (DNR)

This variable indicates if a licensed physician documented a patient as DNR in medical records. Individuals sustaining "brain death" or undergoing organ harvesting do not count as DNR. This variable is coded as "yes" or "no" within the PTSF database and does not indicate if the patient had an out-of-hospital DNR order or a physician ordered DNR order.

Transportation Time

Transportation time was calculated using the date and time provided in the PTSF database for when the scene provider left for the scene and when the patient arrived and was admitted to the hospital emergency department.

Functional Independence Level

The PTSF requires that all individuals entered in the PTOS receive the Functional Independent Measurement (FIM) (Hamilton, Granger, Sherwin, Zielezny & Tashman, 1987).

On discharge, but not earlier than 48 hours before discharge, all trauma patients are evaluated by a trauma unit nurse and given an FIM score. The categories evaluated on the FIM are feeding, transfer mobility, locomotion, expression, and social interaction. For each category, a value of 1 to 4 is assigned: 4 denotes complete independence, 3 indicates independence with some supporting device, 2 means modified dependence, and 1 signifies complete dependence.

Chapter 3

RESULTS

The following results are presented using effect sizes rather than *p*-values. Therefore, results with effect sizes (measured by R^2 or Cox & Snell R^2) of less than 0.1 were not considered significant and those with small (0.1-0.3) to large (> 0.5) effect sizes will be discussed in greater detail.

There were 19,004 moderate to severe traumatic brain injuries (fatal and nonfatal) sustained by adults (ages 18 and above) from 1992 through 2009 in the 31 trauma centers. The typical bimodal distribution observed in adult head trauma was evident in the data: ages 15-25 and 65-90. Young adults (15-25 years of age) showed the highest TBI incidence, and accounted for 6,128 (32%) of the injuries. The elderly sample (65-90) accounted for 3,423 (18%) of the total adult injuries.

The Elderly Sample

Within the elderly sample (ages 65-90; mean = 77.1, SD = 6.8), 57% were male and 43% were female. The sample was comprised of the following racial groups: White (88%), Black (8%), Asian (1%), and race for the remaining individuals (3%) was unreported or unknown. In regard to fatality rate, of the 3,423 elderly individuals sustaining TBI in Pennsylvania between 1992 to 2009, in all trauma centers, a total of 2,104 individuals (62%) had fatal injuries. However, there was a downward trend in the fatality rate over time; in 1992 the fatality rate was 68%, 1995: 68%, 1998: 65%, 2001: 63%, 2004: 57%, and 2007: 57%.

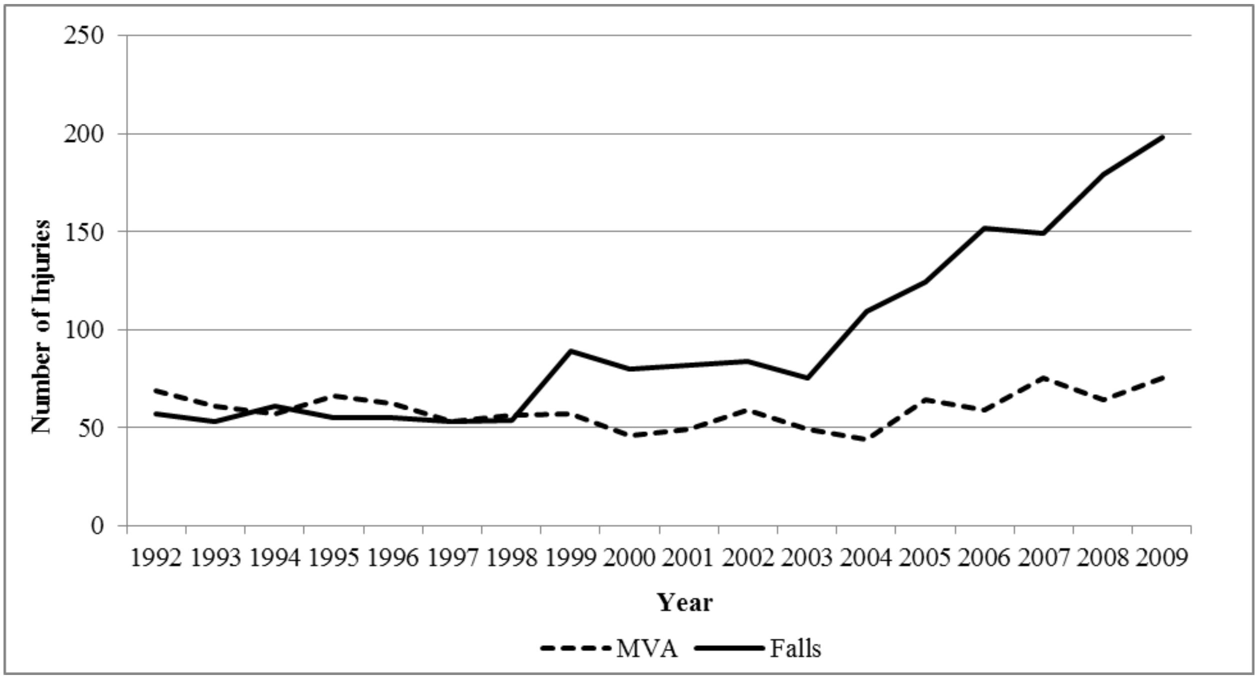
Table 2 shows the mechanisms of injury in the elderly sample for each year. The data indicate that motor vehicle accidents (MVA) were the primary mechanism of injury in the elderly up until 1997 (with the exception of 1994), but since that time, falls in the elderly were the leading cause of TBI. More specifically, falls accounted for 38% of injuries in 1992, but by 2009 they accounted for about 65% of the moderate to severe injuries sustained by elderly individuals in PA. To further demonstrate changes in mechanism of injury over time, the raw number of injuries (fatal and nonfatal) for MVAs and Falls are shown for each year in Figure 2.

Table 2. Mechanism of Injury in the Elderly

Year	MVA Traffic	MVA non Traffic	Falls	Suicide/Self-Inflicted Injury	Homicide/Injury Inflicted by Others
1992	**47.0% (71)**	2.6% (4)	38.4% (58)	6.0 % (9)	3.3% (5)
1993	**46.4 (64)**	.7 (1)	40.6 (56)	5.1 (7)	1.4 (2)
1994	38.2 (60)	1.3 (2)	**43.9 (69)**	8.3 (13)	3.8 (6)
1995	**46.2 (66)**	0 (0)	41.3 (59)	7.0 (10)	.7 (1)
1996	**43.8 (64)**	.7 (1)	39.0 (57)	8.9 (13)	.7 (1)
1997	**41.4 (53)**	1.7 (2)	44.5 (57)	3.9 (5)	.8 (1)
1998	41.0 (59)	.7 (1)	**43.8 (63)**	4.2 (6)	2.8 (4)
1999	33.3 (60)	.6 (1)	**51.7 (93)**	6.1 (11)	3.3 (6)
2000	28.4 (46)	1.9 (3)	**55.6 (90)**	5.6 (9)	2.5 (4)
2001	32.1 (52)	1.2 (2)	**56.8 (92)**	3.1 (5)	1.2 (2)
2002	33.3 (58)	1.1 (2)	**51.7 (90)**	5.7 (10)	1.7 (3)
2003	32.5 (52)	.6 (1)	**50.6 (81)**	6.3 (10)	3.1 (5)
2004	25.7 (49)	0 (0)	**61.8 (118)**	3.7 (7)	2.6 (5)
2005	28.3 (65)	1.3 (3)	**58.3 (134)**	5.2 (12)	0 (0)
2006	22.8 (61)	.7 (2)	**61.6 (165)**	5.2 (14)	2.6 (7)
2007	29.6 (76)	1.2 (3)	**61.9 (159)**	.8 (2)	.8 (2)
2008	22.6 (68)	1.0 (3)	**63.8 (192)**	2.7 (8)	1.3 (4)
2009	24.2 (80)	.6 (2)	**65.0 (215)**	4.2 (14)	1.2 (4)

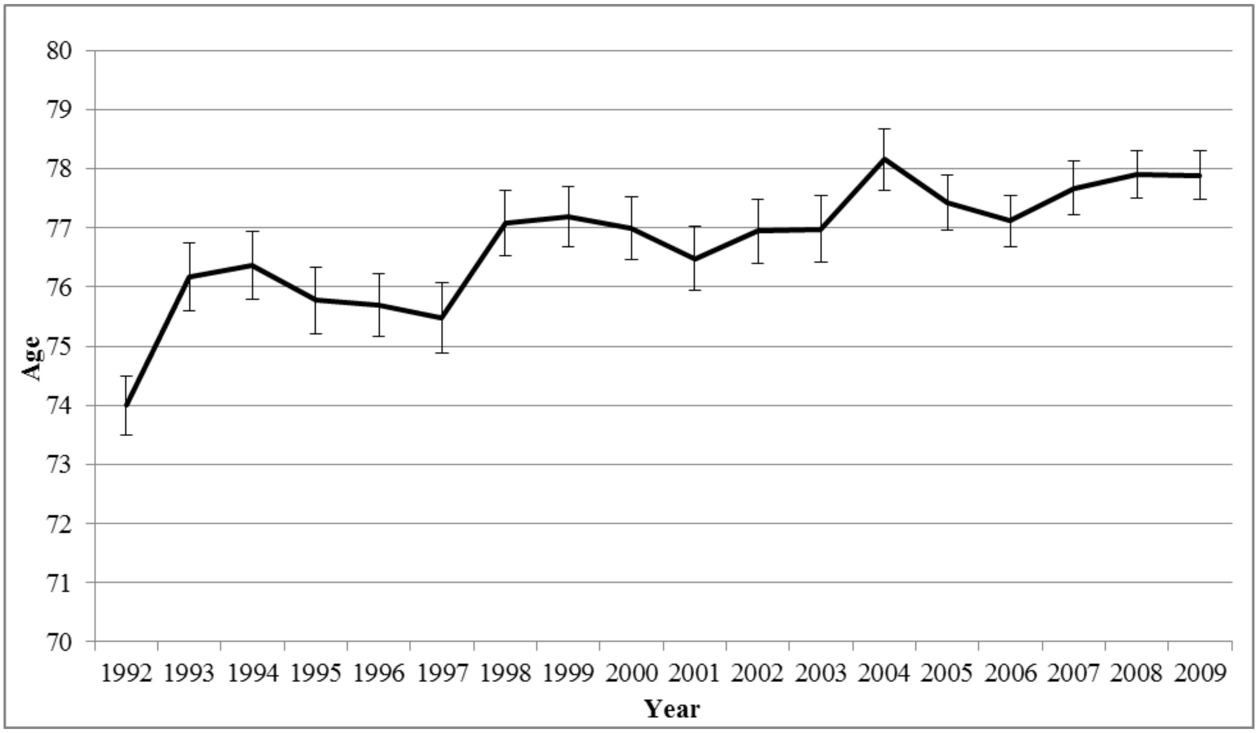
Note: Primary mechanism of injury for each year is in bold.

Figure 2. Number of MVA and Falls Over Time



The change in injury age within the elderly sample over time is shown in Figure 3. Mean age of injury in the elderly increased by 4.6 years between the years 1992 to 2009. Mean FIM scores and GCS scores over time are shown in Table 3. When injury year was used to predict variance in FIM and GCS scores over time, the effect size was trivial (<.1) and was not considered to be significant.

Figure 3. Increase in Age of Injury of TBI in the Elderly



Note: Graph above includes mean age of injury for each year with corresponding standard error bars.

Table 3. Mean FIM and GCS Scores Over Time in the Elderly

Year	FIM Mean (SD)	GCS Mean (SD)
1992	11.45 (5.94)	4.95 (2.90)
1993	10.67 (5.65)	6.00 (3.14)
1994	12.12 (5.19)	6.21 (3.27)
1995	11.70 (6.30)	5.31 (2.66)
1996	11.21 (5.52)	5.53 (3.04)
1997	9.90 (4.77)	5.09 (2.86)
1998	11.35 (5.79)	6.10 (3.12)
1999	9.71 (5.19)	5.51 (3.08)
2000	13.12 (5.46)	5.48 (2.96)
2001	9.60 (4.77)	5.47 (3.20)
2002	11.58 (5.27)	5.91 (3.01)
2003	10.89 (4.76)	6.21 (3.10)
2004	11.02 (5.49)	6.10 (3.14)
2005	10.79 (5.34)	6.06 (3.03)
2006	11.39 (5.60)	6.13 (3.09)
2007	11.82 (5.22)	6.19 (3.11)
2008	11.01 (5.69)	6.15 (3.16)
2009	12.23 (5.27)	5.86 (3.08)

Testing Hypothesis 1a: Incidence Rates and TBI Risk in the Elderly

Of the 31 trauma centers in the state of Pennsylvania, 22 have been accredited and present in the PTOS for every year from 1992 to 2009. To document changing trends over time, the current analysis focuses on those 22 trauma centers. Within the 22 trauma centers, there was a total of 3,228 elderly individuals that sustained TBI (ages 65-90; mean = 74.0, SD = 8.4). In regard to gender, 57% were male and 43% were female. The sample was comprised of the following racial groups: White (86%), Black (9%), Asian (.8%), and race for the remaining individuals (4.2%) was unreported or unknown. As seen in Figure 4, after controlling for population growth, the rate of elderly TBI (fatal and nonfatal injuries) has increased by 87%. Injury year predicted variance in the incidence of elderly TBI in Pennsylvania ($R^2 = .69$, $\Delta R^2 = .69$, ΔF (1, 16) = 36.05, $p < .001$).

Figure 4. Elderly TBI in Pennsylvania

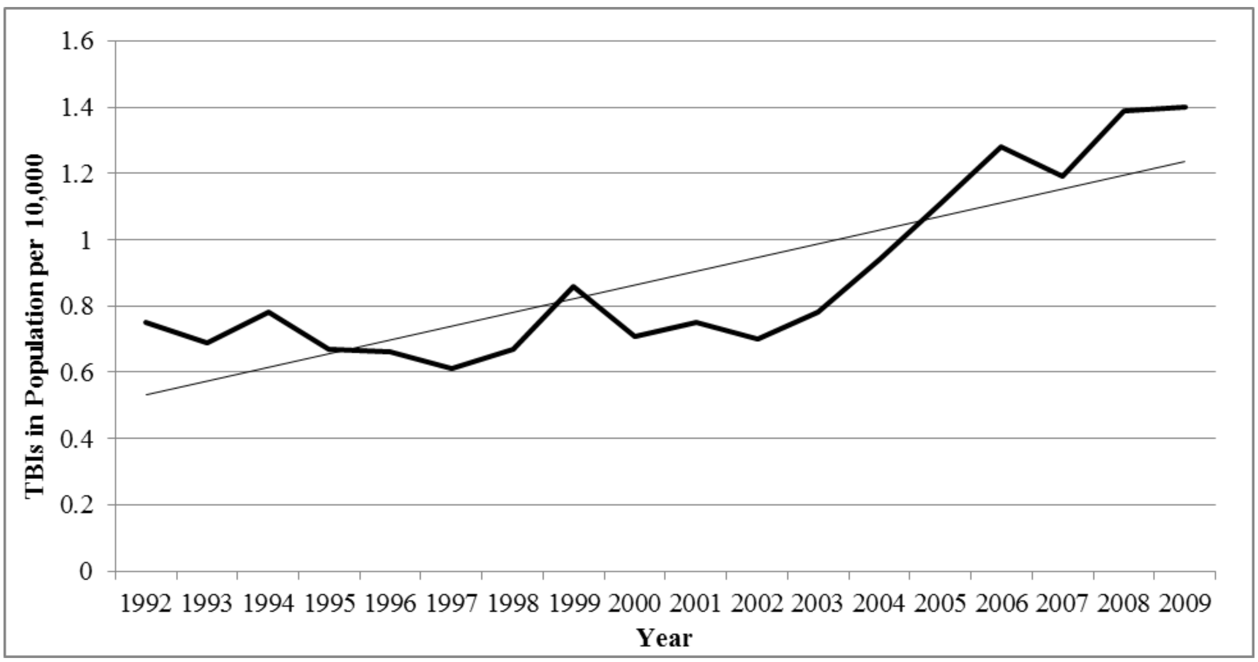


Figure adapted from Ramanathan, McWilliams, Schatz & Hillary, 2012.

Given that elderly TBI has almost doubled in the past 18 years, it was of interest to examine if different elderly age groups were increasing at different rates or contributing to this increase in differing proportions. Therefore, a post-hoc analysis was performed with the elderly subgroups described below in Table 4. Incidence rates in the 22 trauma centers for the YE, ME, and OE groups are shown in Figure 5, indicating that TBI has increased in all groups. Incidence rates were then examined by calculating the proportion of total elderly TBI (ages 65-90) that each elderly subgroup (YE, ME, and OE) accounted for. Figure 6 indicates that the proportion of OE TBI to total elderly TBI has increased over time relative to the other elderly TBI subgroups.

Table 4. Elderly Subgroups

Group	N	Age
Young Elderly	1079	69.1 (SD=2.6)
Middle Elderly	1348	78.0 (SD=2.6)
Old Elderly	799	85.8 (SD=2.2)

Figure 5. TBI in Elderly Subgroups Over Time

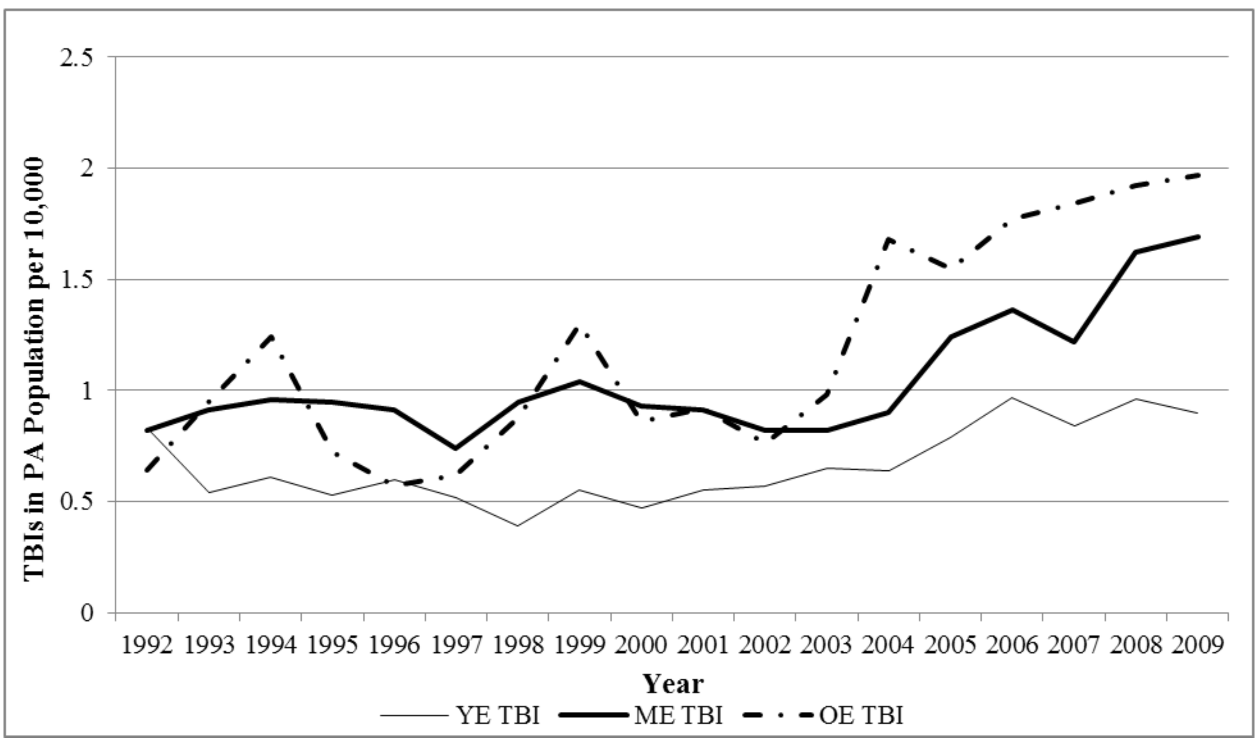


Figure adapted from Ramanathan et al., 2012.

Figure 6. Changes in the Proportions of TBI in Elderly Subgroups

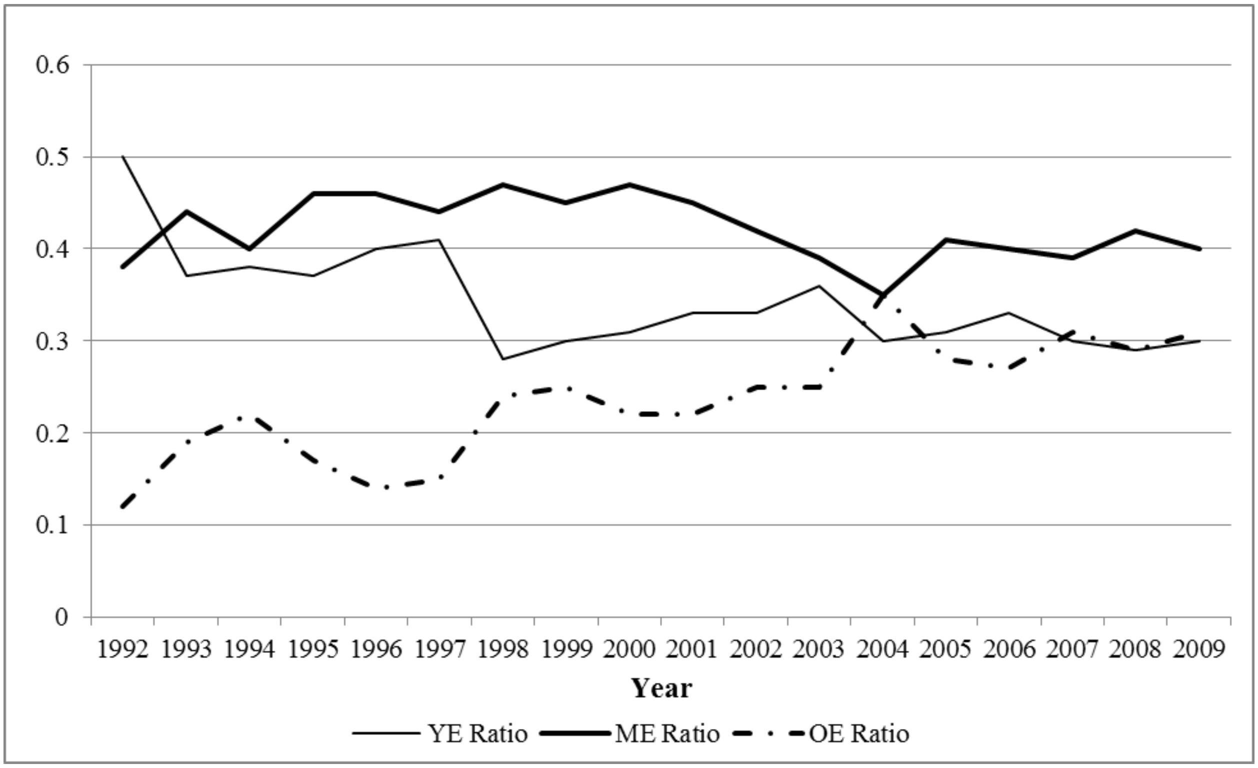


Figure adapted from Ramanathan et al., 2012.

Testing Hypothesis 1b: FIM Scores and Fatalities by Age Group

When the elderly age groups (YE, ME, and OE) were used to predict outcomes following TBI, significant results were only found when predicting fatalities and DNR orders. ANOVA analyses indicated that there were no between-group differences in FIM scores when examining elderly age groups. Additionally, there were no between age group differences in injury severity.

When age groups and odds of having a fatal injury were examined with logistic regression, the model was significant and produced a small effect size when the YE and OE groups were compared, indicating that increased age increased the likelihood of having a fatal injury. This relationship was not evident when comparing the ME and OE groups, see Table 5.

Table 5. Elderly Subgroups Predicting Fatal Injuries

Groups Compared	*B*	Exp (B)	Wald
YE vs OE	-.44	.65	67.43 *
ME vs OE	-.02	.98	.15

*small effect size

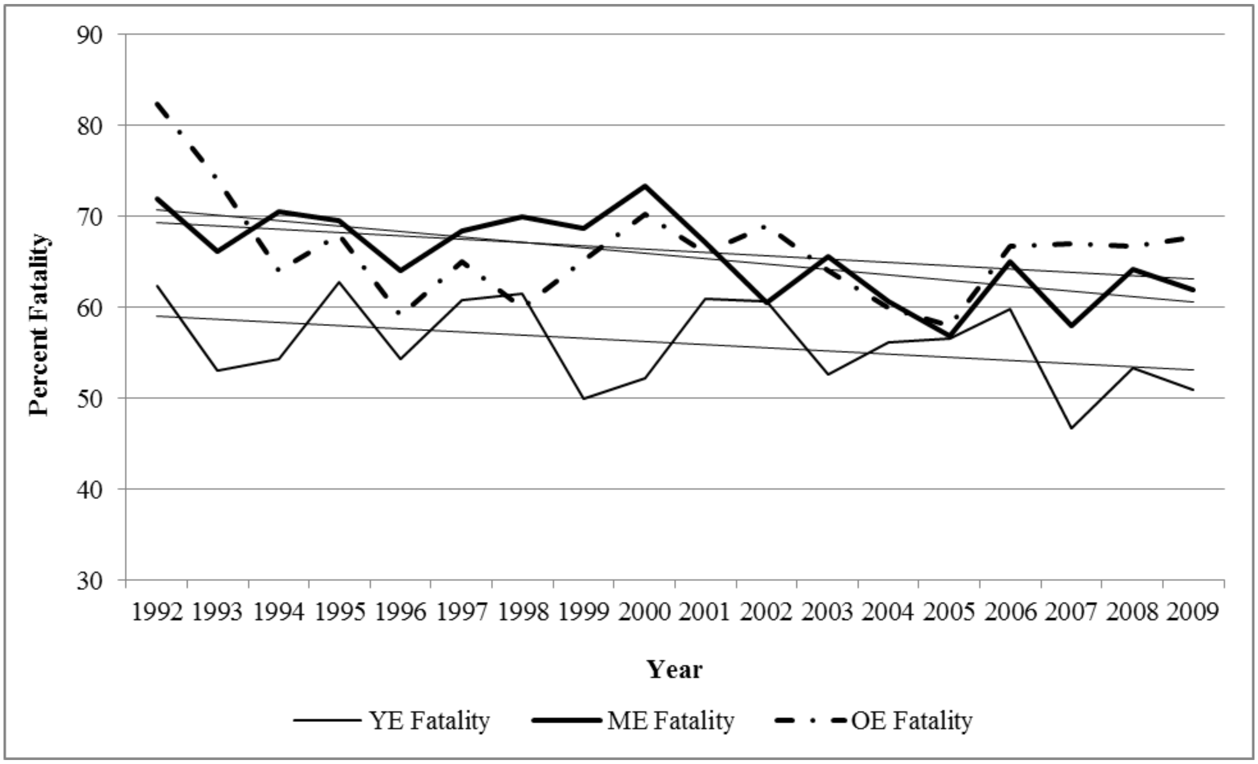
Descriptions of injury and outcome related variables for the elderly age groups in all trauma centers are provided in Table 6. Although there were no between-group differences in age groups for GCS scores and FIM scores, there is a trend indicating that GCS scores increase (injury severity decreases) and FIM scores decrease with increased elderly group age.

Table 6. Elderly Subgroups and Injury Related Variables

Group (N)	Average Age Mean (SD)	Average GCS Mean (SD)	Percent Fatality	Percent with Positive DNR	Primary Mech. of Injury	FIM Mean (SD)
Young (1118)	69.2 (SD = 2.6)	5.5 (SD = 3.0)	56%	33 %	Falls (43% , n = 484)	12.3 (5.6)
Middle (1439)	78.0 (SD = 2.6)	5.8 (SD = 3.0)	65%	48%	Falls (56%, n = 813)	10.9 (5.2)
Older (866)	85.8 (SD = 2.2)	6.4 (SD = 3.2)	64%	47%	Falls (64%, n = 551)	9.9 (5.0)

Given that prior results showed a decrease in the elderly TBI fatality rate over time, an additional post-hoc analysis was performed to examine if this trend was present in each elderly subgroup. As seen in Figure 7, there is a downward trend in fatality rates in each elderly subgroup.

Figure 7. Fatality Rates in Elderly Subgroups



Testing Hypothesis 2: Influence of Age on DNR Orders

When elderly age subgroups were used to predict DNR orders in logistic regression, the model was significant and produced a moderate effect size when comparing the OE group to both the YE and ME groups. Thus, being in the OE group increased the likelihood of having a positive DNR order, see Table 7.

Table 7. Elderly Subgroups Predicting DNR Orders

Groups Compared	***B***	**Exp (B)**	**Wald**
YE vs OE	1.10	3.02	324.47 **
ME vs OE	.37	1.45	45.25 **

**moderate effect size

Testing Hypothesis 3: Relationship Between Pre-Hospital Variables and DNR Orders

Increased transportation time was hypothesized to increase the odds of having a positive DNR order in the elderly. When examined in logistic regression, the results (see Table 8) indicated that increased transportation time did significantly increase the likelihood of having a positive DNR order and produced a small effect size. This same model was not significant when young adults were examined; therefore in the younger age groups, transportation time did not predict the likelihood of having a DNR order.

Table 8. Logistic Regression of Transportation Time Predicting DNR Orders

Predictor of DNR	***B***	**Exp (B)**	**Wald**
Transport Time	-.001	1.00	48.41 *

*small effect size

Injury severity at the scene was also examined as a predictor of the DNR order. Logistic regression showed that increased GCS score (increase in GCS indicates decreased severity) decreased the probability of having a positive DNR order in the elderly. In addition, this model was also significant in the young adult group, and both models produced small effect sizes. See Table 9.

Table 9. Logistic Regression of GCS Predicting DNR Orders

Predictor of DNR	***B***	**Exp (B)**	**Wald**
Elderly GCS score	.04	1.04	24.38 *
Young Adult GCS score	.17	1.18	58.17 *

*small effect size

Furthermore, given that injury severity was correlated with transportation time (r (3419) = .10, *p < .001)*, an additional logistic regression was performed to examine if transportation time still predicted the likelihood of having a DNR order, even when injury severity was controlled for in the elderly sample. The DNR order variable was entered as the dependent factor, while GCS score was entered in the first step and transportation time was entered in the second step. When tested, both steps were significant, and increased transportation time still predicted an increased probability of having a positive DNR order, see Table 10.

Table 10. Logistic Regression Predicting DNR Orders Using GCS and Transportation Time

Predictor of DNR	***B***	**Exp (B)**	**Wald**
GCS	.04	1.04	13.97 *
Transport Time	-.002	1.00	33.24*

*small effect size

Testing Hypothesis 4: Geographic Location Predicting Injury and Outcome Variables

When examining geographic location, only individuals that had the county of injury coded in the database were used. Therefore, analyses examining rural and urban TBI used the samples described in Table 11.

Table 11. Descriptives of Urban and Rural Groups by Age

	Urban Elderly	**Rural Elderly**	**Urban Young Adults**	**Rural Young Adults**
N	2343	785	4041	1604
Gender	Male: 56% Female: 44%	Male: 59% Female: 41%	Male: 79% Female: 21%	Male: 74% Female: 26%
Race	White: 84% Black: 11% Asian: 1% Other/Unknown: 4%	White: 96% Black: 1% Asian: 1% Other/Unknown: 2%	White: 60% Black: 30% Asian: 1% Other/Unknown: 9%	White: 92% Black: 3% Asian: .4% Other/Unknown: 4.6%

The influence of just geographic location on outcome following TBI was tested before testing the hypothesis regarding outcome differences between Urban Elderly, Rural Elderly, and Rural Young Adult groups.

Geographic Location Predicting Injury Severity

In ANOVA analyses, geographic location was entered as the independent variable and injury severity was the outcome variable. When tested, the model did not produce an effect size above .1, therefore there were no between-group differences in GCS scores ($F(1, 8771) = 46.08$, $p < .001$).

Geographic Location Predicting Transport Time

ANOVA was also used to test whether injury county predicted difference in transportation time. This analysis also produced a trivial effect size, indicating that rural and urban counties did not differ in transport time to a trauma center ($F(1, 8769) = 128.73$, $p < .001$).

Geographic Location Predicting GCS Change

In ANOVA analyses, geographic location did predict differences in GCS score from the scene to admission to the trauma center, ($F(1, 8771) = 353.83$, $p < .001$).

Geographic Location and Fatality

Logistic regression was used to test whether the odds of having a fatal injury increased depending of geographic location of the injury; however, these results produced a trivial effect size of < .01 and were not considered to be significant.

Geographic Location Predicting DNR Orders

When geographic location was entered as the predictor variable, there were no significant differences in the likelihood of having a positive DNR order depending on whether an individual had an injury in an urban or rural location.

Geographic Age Groups Predicting Outcome Differences

Table 12 shows the means, standard deviations, and frequencies for injury related outcome variables in the groups to be compared (Urban Elderly, Rural Elderly, and Rural Young Adults). Tables 13a and 13b show the logistic regressions comparing Urban Elderly, Rural Elderly, and Rural Young Adults on the dichotomous injury related outcome variables of fatalities and DNR orders. When Urban Elderly, Rural Elderly, and Rural Young Adult groups were used to predict the other outcome variables (GCS, transport time, and change in GCS scores), ANOVA analyses indicated that there were no significant between-group differences.

Table 12. Outcomes in Urban and Rural Groups by Age

Outcome Variables	**Urban Elderly**	**Rural Elderly**	**Rural Young Adults**
GCS	5.8 (SD=3.0)	6.0 (SD=3.2)	5.7 (SD=3.0)
Transport Time (minutes)	65.4 (SD=124.6)	110.6 (SD=172.1)	82.3 (SD=92.3)
Change in GCS	.2 (SD=2.8)	-1.0 (SD=3.3)	-1.5 (SD=3.2)
Fatalities	61.2%	62.4%	28.9%
Positive DNR Order	34.7%	38.5%	4.3%

Tables 13a and 13b. Logistic Regressions Predicting Fatalities and DNR Orders in Urban and Rural Groups by Age

13a. Fatalities

Groups Compared	***B***	**Exp (B)**	**Wald**
Urban Elderly vs. Rural Elderly	-.02	.98	.13
Rural Elderly vs. Rural Young Adults	-1.45	.23	1000.35 *

*indicates small effect size

13b. Positive DNR Orders

Groups Compared	***B***	**Exp (B)**	**Wald**
Urban Elderly vs. Rural Elderly	-.11	.90	4.03 *
Rural Elderly vs. Rural Young Adults	-2.59	13.28	887.78 *

*indicates small effect size

Although there were no significant effect sizes when rural and urban groups by age were used to predict GCS, transport time, and change in GCS scores, several small effects were found in the logistic regressions. When examining if geographic age groups predicted odds of a fatal injury and positive DNR order, there was no significant difference between the Urban and Rural Elderly groups, but when Rural Elderly and Rural Young Adults were compared, the likelihood of having a fatal injury was more likely in the elderly age group in a rural location. Furthermore, when Urban and Rural Elderly individuals were compared with DNR order as the dependent variable, individuals that were Rural Elderly were more likely to have a positive DNR compared to Urban Elderly individuals. In addition, when the Rural Elderly group was compared to the Rural Young Adults, Rural Elderly individuals were again more likely to have a positive DNR order.

Testing Hypothesis 5: Geographic Location Predicting Changes in Fatalities and Injury Severity

As previously demonstrated, GCS did not differ significantly between urban and rural injury locations. In addition, linear regression indicated that injury year did not predict variance in GCS score over time in the elderly. It was hypothesized that there would be a trend of less severe injuries over time in urban areas (increased GCS) and more severe injuries over time in rural areas (decreased GCS). The graph in Figure 8 shows that there was actually a similar trend in GCS scores over time and that in both rural and urban injury counties there was an increase in the GCS score, indicating that there is a trend in injuries becoming less severe over time. The mean and standard deviation for GCS scores over the past 18 years in elderly individuals in urban and rural areas was 5.71 (SD=3.03) and 5.96 (SD=3.18), respectively.

When fatalities were examined over time in different counties, injury year and county did not predict fatal injuries over time. However, a downward trend is evident in fatality rates over time in both rural and urban counties as seen in Figure 9. In elderly individuals in urban areas, the average percent fatality rate was 61.6% and in rural areas the average fatality rate was 62.6%.

Figure 8. Injury Severity Scores Over Time in Urban and Rural Areas

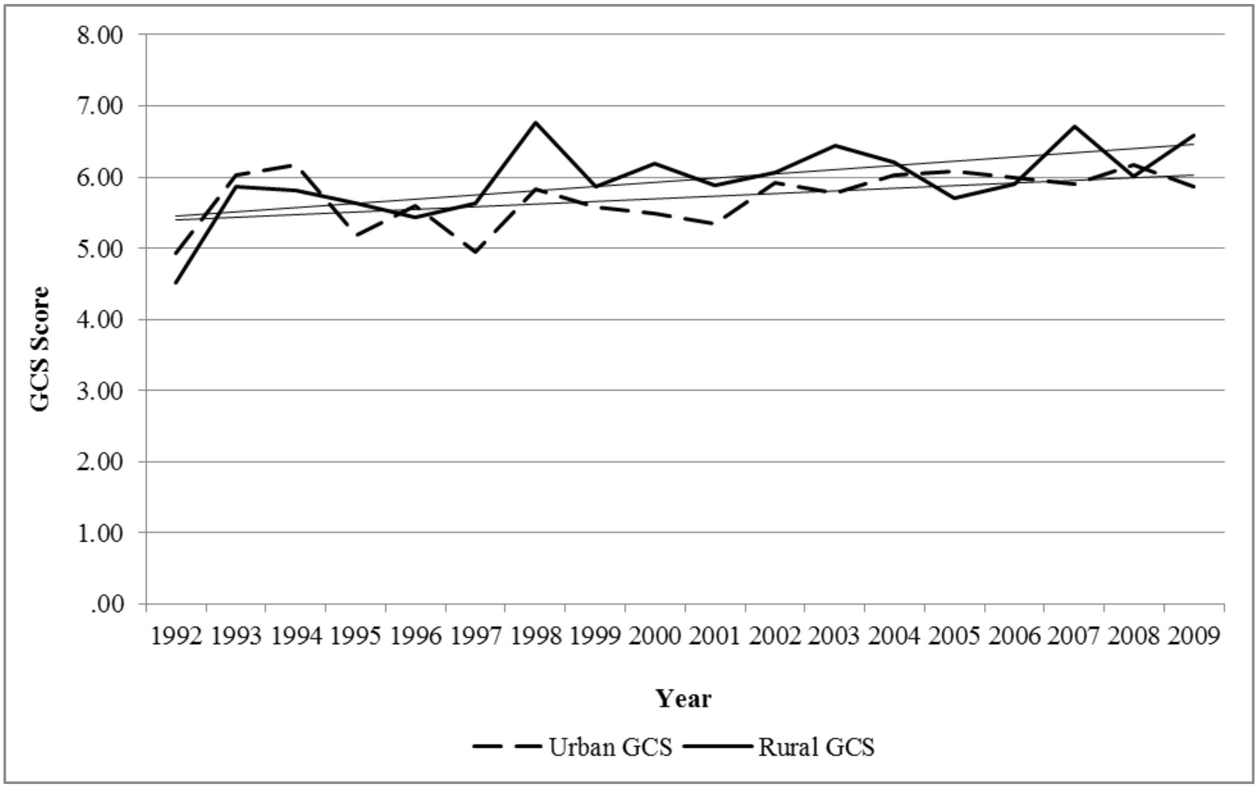
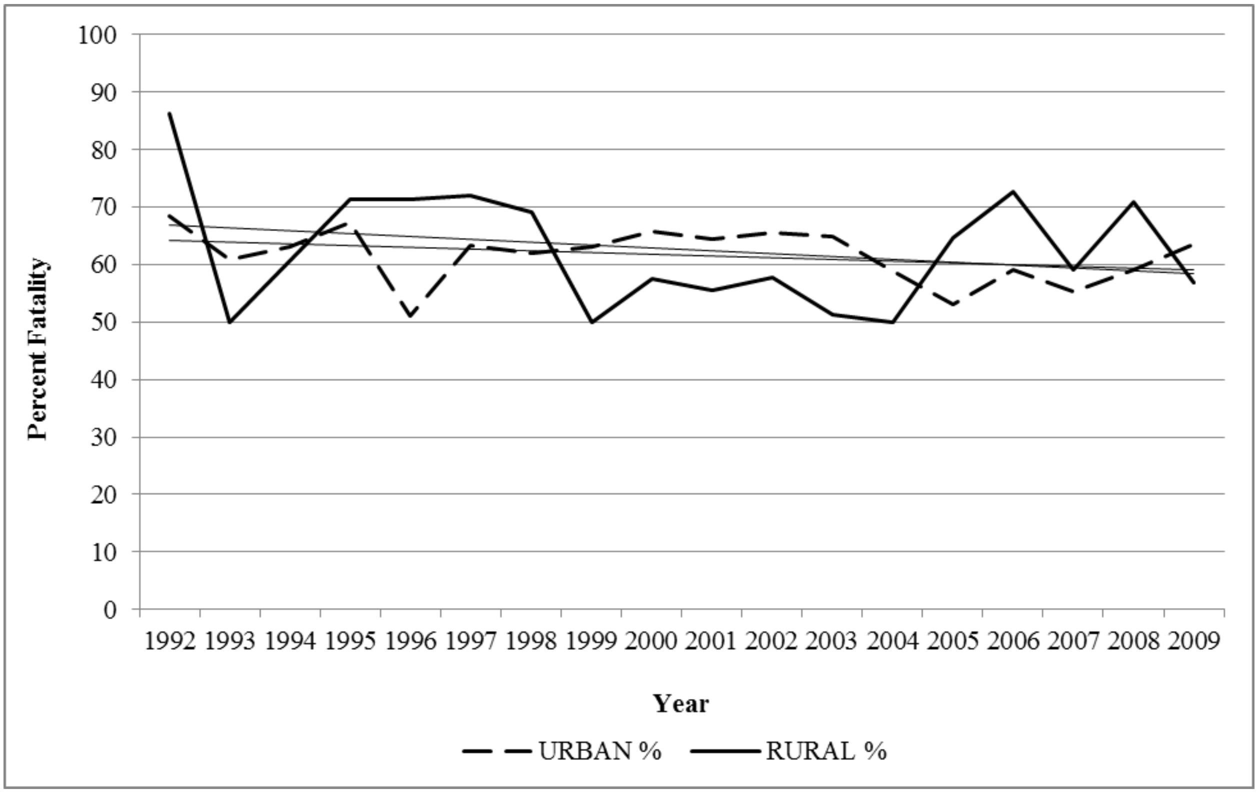


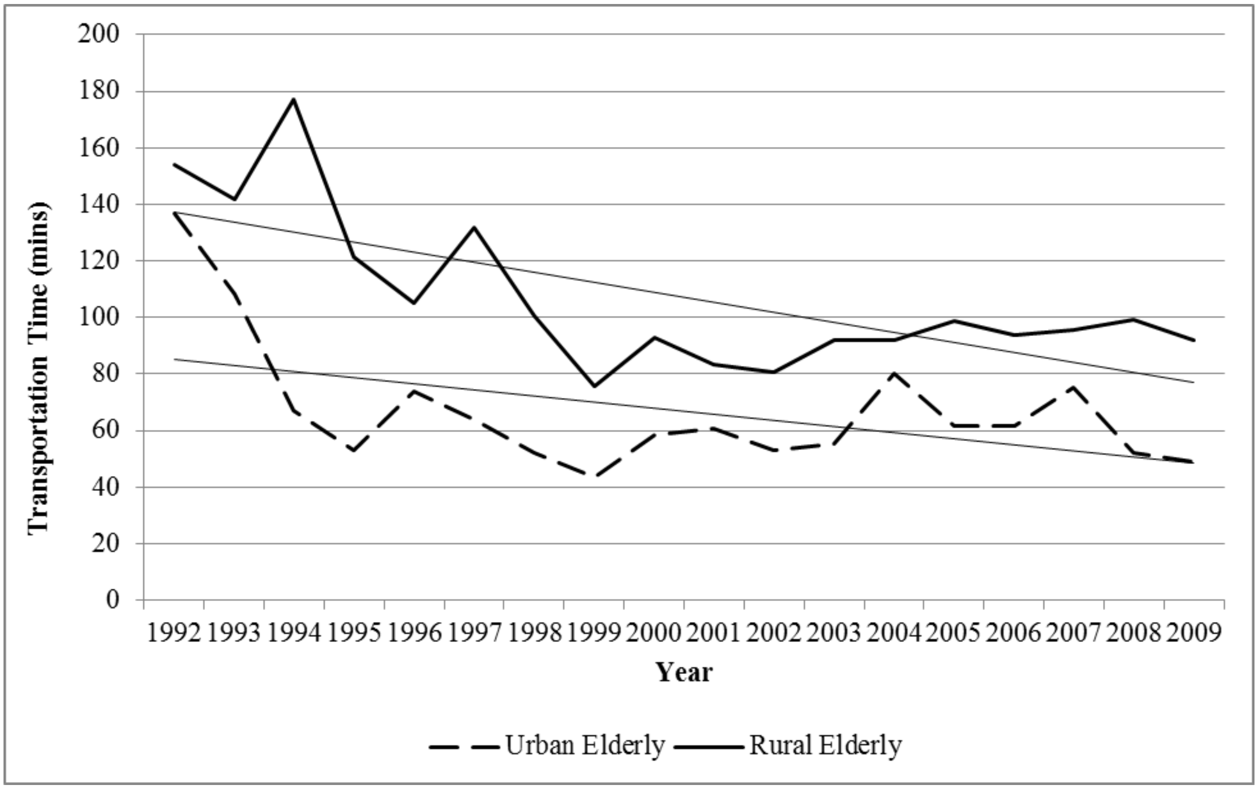
Figure 9. Fatality Rates Over Time in Urban and Rural Areas



<u>Testing Hypothesis 6: The Relationship Between Transport Time and Outcome</u>

When transportation time was examined in urban elderly and rural elderly individuals through ANOVA analyses, there were no between-group differences. In the urban elderly group, the average transportation time was 65.4 minutes (SD=124.6) and in the rural elderly group the average time was 110.6 minutes (SD=172.1). Additionally, injury year did not predict significant variance in transportation time in linear regression. However, as seen in Figure 10, there is a trend over time indicating a decrease in transportation time from 1992 to 2009 in urban and rural locations. In the urban elderly group, transportation time decreased overall by 88 minutes from 1992 to 2009, a 36% decrease. Within the rural elderly group, it decreased by 62 minutes, which was a 60% decrease in transportation time over time.

Figure 10. Transportation Times Over Time in Urban and Rural Areas



As seen in Figure 9, there are larger differences in transportation time during the 1990's than when compared to differences in transportation time between urban and rural elderly individuals from 2000 to 2009. Therefore, a post-hoc analysis was performed to examine if there were between group differences (Urban Elderly vs. Rural Elderly) in transportation time when first examining the years 1992 to 1999, and then when examining 2000 to 2009, but neither produced any between-group differences.

An additional post-hoc analysis was performed to examine if transportation time differed between the 1990's and 2000's when the Urban Elderly and Rural Elderly groups were examined separately. However, for both the Urban Elderly and Rural Elderly, there were no differences between the 1990’s and 2000’s in regard to transportation time. Furthermore, when transportation time was used to predict outcome (FIM scores and fatalities), the models did not produce a significant effect size. Post-hoc analyses were performed to examine if distinct ranges in transportation time (high versus low) would indicate differences in FIM scores and fatalities. However, when using a median split with transportation time and subsequently examining the upper and lower quartiles in the data did not produce significant differences in the Urban Elderly or Rural Elderly groups on FIM scores and fatalities. Thus, differences in transportation time did not predict outcome following TBI.

Testing Hypothesis 7: Examining the Group with the Poorest Outcomes Following TBI

In order to examine what demographic factors combined predicted the worst outcomes following TBI, specific subgroups were formed based on age, geographic injury location, and gender. Average injury severity was calculated for each group, and also each group was compared on two outcomes variables: fatality rate and functional outcome. Descriptives for all 16 groups are shown in Table 14.

Table 14. Subgroups Based on Age, Geographic Location, and Gender

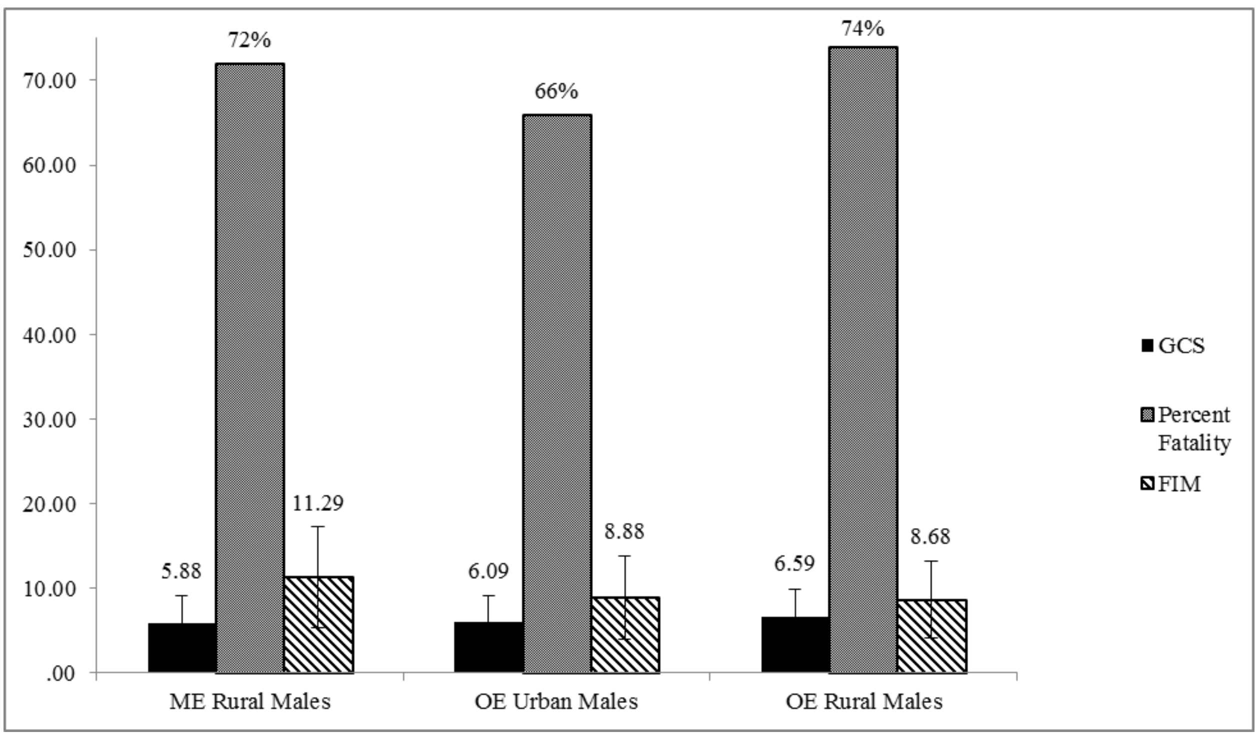
Group	N	GCS Mean (SD)	Percent Fatality	FIM Mean (SD)
YA Urban Males	3183	**5.0 (2.7)** *	46.8%	**15.0 (5.6)** *
YA Rural Males	1193	5.7 (3.0)	**28.8** *	**14.7 (5.5)** *
YA Urban Females	857	**5.3 (2.7)** *	33.3	14.6 (5.6)
YA Rural Females	410	5.6 (2.9)	**29.5** *	13.8 (5.8)
YE Urban Males	517	5.4 (3.0)	58.0	12.7 (5.6)
YE Rural Males	168	5.7 (3.0)	53.0	12.1 (5.8)
YE Urban Females	262	5.5 (3.0)	53.4	11.5 (5.6)
YE Rural Females	85	5.8 (3.1)	58.8	11.7 (5.2)
ME Urban Males	524	5.7 (2.9)	64.9	11.5 (5.3)
ME Rural Males	202	5.9 (3.2)	**72.3** *	11.3 (6.0)
ME Urban Females	447	5.9 (3.1)	62.2	11.5 (5.0)
ME Rural Females	133	5.7 (3.1)	61.7	11.3 (5.1)
OE Urban Males	279	6.1 (3.1)	65.9	**8.9 (4.9)** *
OE Rural Males	95	**6.6 (3.3)** *	**73.7** *	**8.7 (4.6)** *
OE Urban Females	314	6.3 (3.1)	60.8	9.9 (5.2)
OE Rural Females	102	**7.1 (3.3)** *	52.0	12.0 (4.4)

Note: YA=Young Adults, YE=Younger Elderly, ME=Middle Elderly, OE=Older Elderly

In bold: Two best scores/outcomes in each category are in blue (*) and the bottom two scores/outcomes in each category are in red (*).

Based on the descriptive analyses, the group with the poorest outcomes (highest fatality rates and lowest functional scores) included the Older Elderly Rural Males, however this group did not sustain the most severe injuries. Figure 11 shows the Older Elderly Rural Male group with the two other groups with the second highest fatality rate (ME Rural Males) and second lowest FIM score at discharge (OE Urban Males). As seen in the graph, although OE Rural Males have the poorest outcome based on fatalities and FIM scores, compared to the other two groups, the average injury severity score is higher (indicating less severe injuries) in this group.

Figure 11. TBI Injury Severity, Fatality Rates, and FIM Scores in At-Risk Groups



The results indicate that when considering all groups, the most severe injuries were sustained by young adults in urban injury locations. The initial hypothesis, that Older Elderly Rural Females sustain the most severe injuries, have the highest fatality rates, and lowest FIM scores at discharge, was not supported.

Chapter 4

DISCUSSION

The current study used statewide data from the Pennsylvania Trauma Systems Outcome Study and provided a comprehensive description of TBI in older age groups and in rural and urban injury locations. More specifically, this study focused on how age, geographic location, gender, and also pre-hospital related variables ultimately influenced outcomes, such as fatalities and functional scores at discharge, following moderate to severe TBI. The results from this study elucidate the impact that age and geographic injury location can have on outcomes following TBI. There are several important findings in the current study that will be discussed in greater detail below, including: 1) Increased incidence of TBI in the elderly, 2) Increased fatalities and positive DNR orders in the OE group, 3) Longer transportation times predict DNR orders, 4) Higher DNR orders and fatalities in Rural Elderly individuals, and 5) Poorest Outcomes Following TBI in Older Elderly Rural Males.

Increases in Elderly TBI Incidence Rates

The current data reveal that the incidence of TBI in the elderly in Pennsylvania approximately doubled between 1992 to 2009 (increasing by 87%). The increase in TBI is evident even after controlling for the overall population growth and the number of trauma centers contributing to the database during that period. Dramatic increases in the incidence of TBI in the elderly have been similarly demonstrated in prior research (Fletcher et al., 2007; Kannus et al., 1999; Stevens & Adekoya, 2001). Given worldwide projected increases in the elderly population, including industrialized nations such as Australia, Canada, France, Germany, Japan, New Zealand, and the United Kingdom (Anderson & Hussey, 2000), increasing TBI in the elderly may be a global issue.

As previously noted, MVAs in the general population have decreased over time due to greater awareness and law enforcement (Federal Highway Administration, 1999 and 2009); but falls, and resulting TBI, may have increased over time due to a lack of awareness and preventative efforts. Currently, 51% of all elderly TBI is due to falls (Thompson, McCormick & Kagan, 2006) and 8% of individuals ages 65 years and older that visit hospital emergency departments each year due so because of a fall-related injury (King, 2003). Additionally, work examining the rate of fall-induced TBI deaths from 1989 to 1998 indicates a 57.8% increase in men and 42.4% increase in women over time (Stevens & Adekoya, 2001), indicating that falls resulting in fatalities are increasing.

It is possible that the increase in injury age and shift to falls as the primary mechanism in the data can be explained by an increase in life expectancy from medical advances and healthier lifestyle choices (Kannus, Parkkari, Koskinen, Niemi, Palvanen, Jarvinen & Vuori, 1999). Currently, people live longer than at any time in the past, as shown by the dramatic increase in US life expectancy which rose from 47.3 years of age in 1900 to 76.9 years of age in 2000 (He, Sengupta, Velkoff & DeBarros, 2005). A longer life-span may mean that individuals have more premorbid functional impairments when sustaining TBI (Kannus et al., 1999).

Although another possibility may be that elderly individuals are more active today than they were in the past, the literature pertaining to this is currently mixed. Some work shows that activity levels in the elderly have increased over time (Freedman et al., 2002; Murabito, Pencina, Zhu, Kelly-Hayes, Shrader & D'Agostino, 2008; Victorino & Gauthier, 2005), and this active lifestyle may make individuals more susceptible to falling. However, other work indicates that although leisure time physical activity has increased (between 1990 to 2000) there have actually been decreases in physical activity in other domains. For example, work-related and household physical activity, as well as physical activity for transportation purposes have all decreased over time (Brownson, Boehmer & Luke, 2005). Notably, this research did not specifically examine the elderly and rather all adults were examined together. Although some research indicates an increase in some physical activity over time, much work demonstrates that even with this slight increase, elderly individuals may not be achieving levels of activity that would be most beneficial for healthy functioning. This may be an important factor, given that exercise can improve balance and reduce the risk of falls and injuries (Gillespie, Robertson, Gillespie, Lamb, Gates, Cumming & Rowe, 2009; Gardner, Robertson, Campbell, 2000). It could be the case that even though life expectancy is increasing, many individuals are still not meeting recommended physical activity levels and are more susceptible to physical injury and detrimental falls. For example, work that has examined activity rates in the elderly have found that few older adults in the US meet recommended physical activity, and more specifically 28-34% of older adults (ages 65-74) are inactive (CDC Agency for Healthcare Research and Quality, 2008). Furthermore, data from the CDC’s Behavioral Risk Factor Surveillance System indicates that among elderly adults in Pennsylvania, there are no significant differences over time in the amount of individuals exercising or meeting recommended activity levels over time from 1996 to 2011. Thus, the increase in life expectancy in the elderly combined with the lack of increase in beneficial levels of physical activity may be contributing to the increase of falls in the Pennsylvania elderly population.

One intriguing finding in post-hoc analyses was that total elderly TBI was not made up of equivalent proportions of individuals from the YE, ME, and OE groups. Although TBI has increased in all the elderly subgroups in Pennsylvania, the OE TBI group made up a greater proportion of the total elderly TBI sample over time. Therefore, it is possible that the OE group is differentially influencing the rise in elderly TBI compared to the YE and ME groups.

Importantly, the oldest elderly individuals in the United States are growing at a rapid pace. Individuals ages 85 years and older totaled 122,000 in 1990, but by the year 2000 this age group had reached 4.2 million (34 times larger than it was in 1990). The rest of the elderly population (ages 65-84) did not increase as dramatically from 1990 to 2000, growing 10 times as large from 3.0 million to 30.8 million individuals. As previously noted, the rapid growth in the older elderly population and increase in fall-related injuries in the US may be due to increases in life expectancy, related to improvements in medical care and nutrition during the century (Kannus et al., 1999). The increase in TBI in the elderly is of great concern, as is the increasing proportion of TBI accounted for by the OE population. Without proper prevention work, the amount of OE TBI may continue to rise given that the older elderly population in the US is projected to be 8.7 million in 2030 and 19 million in the year 2050 (Vincent & Kelkoff, 2010). Additionally, the state of Pennsylvania is one of 10 states projected in the year 2030 to have more individuals above the age of 65 than below the age of 18 (US Census Bureau, 2005). The current study, and other work demonstrating increases in the elderly population and elderly TBI growth rates, demonstrates that the risk for injuries in older age is a critical healthcare issue at the statewide, nationwide, and global levels.

<u>Increased Fatalities and Positive DNR Orders in the OE Groups</u>

In regard to fatality rate, there was a trend of a decrease over time, in all elderly subgroups and in both rural and urban injury locations, indicating that more elderly individuals are surviving moderate to severe TBI, similar to findings by Fletcher and colleagues (2007). When fatality rates by elderly age group (YE, ME, and OE) were examined in the current data, the ME and OE groups had comparable fatality rates (65% and 64%, respectively) which were higher than the fatality rate in the YE group (56%). When elderly age groups were used to predict the likelihood of having a fatal injury in logistic regression, there were no differences when comparing the ME and OE groups; however, when the OE group was compared to the YE group, increased age significantly predicted the odds of having a fatal injury. Therefore, the results indicate that the probability of having a fatal injury does differ between elderly age groups, but this difference is only evident when comparing the extremes of the elderly sample (the YE and OE groups). Survival rate differences between younger and older adults following TBI has been well established in the literature (Amacher & Bybee, 1987; Luerssen, Klauber & Marshall, 1988; Levati, Farina, Vecchi, Rossanda & Marrubini, 1982; Pazzaglia, Frank, Frank, & Gaist, 1975; Signorini, Andrew, Jones, Wardlaw & Miller, 1999; Vollmer et al., 1991) and the current findings extend this literature by demonstrating that younger and older elderly individuals also show differences in fatalities rates. More specifically, individuals above the age of 74 have a greater likelihood of sustaining a fatal injury when compared to individuals under the age of 74.

There are several explanations as to why elderly individuals have higher fatality rates. Advanced age is associated with more cerebral atrophy and intracerebral hematoma, which has been shown to relate to decreased survival rates (Vollmer et al., 1991). In addition, elderly individuals that sustain TBI tend to have more functional and medical problems premorbidly when compared to younger individuals. Therefore, the finding of increased age and fatal outcome is likely due to a combination of anatomical factors and premorbid medical problems common in advanced age.

In regard to DNR orders, a small effect size was found when elderly age groups were used to predict the likelihood of having a positive DNR order. Individuals in the OE group were more likely to have a positive DNR order following TBI compared to both the YE and ME groups. These findings support prior work examining the relationship between increased DNR rates and older age in medical populations in hospital ICU's (Bedell, Pelle, Maher & Clearly, 1996; Shepardson, Younger, Speroff, O'Brien, Smyth & Rosenthal, 1997; Younger, Lewandowski, McClish, Juknialis, Coulton, & Bartlett, 1985; Zimmerman, Knaus, Sharpe, Anderson, Draper, & Wagner, 1986) as well as other work demonstrating a greater likelihood of DNR orders in ICU patients above the age of 85 (Boyd, Teres, Rapoport & Lemeshow, 1996), in patients above the age of 83 on a hospital geriatric ward (Dautzenberg, Bezemer & Duursma, 1994), and in hospitalized patients above the age of 80 (de Vos, Koster & de Haan, 1998). The current study has now provided evidence for a similar trend in a TBI sample, and further demonstrates that the likelihood of having a positive DNR order changes with increased elderly age.

No prior work has specifically examined the reasons why DNR orders are related to increases in age. It could be that as individuals get older, physicians are more likely to initiate conversations about resuscitation with patients and families (Wenger, Pearson, Desmond, Harrison, Rubenstein, Roger & Kahn, 1995). Although, another explanation may be that with increasing age, elderly individuals feel less hope about making full recoveries following hospital stay and could more frequently consider the DNR order, but much research has actually found that many elderly individuals prefer to be resuscitated (Frankl, Oye & Bellamy, 1989; O'Brien, Grisso, Maislin, LaPann, Krotki, Greco, Siegert & Evans, 1995; Torian, Davidson & Fillit, 1992).

Longer Transportation Times Predict DNR Orders

Transportation time was hypothesized to predict DNR orders, fatalities, and FIM scores. The results showed that transportation time demonstrated a small effect only when predicting DNR orders. After controlling for injury severity, the results indicate that increases in transportation time still increase the probability that an elderly individual will have a positive DNR order. This same relationship was not evident in young adults. In post-hoc analyses, increased injury severity was also associated with an increased likelihood of having a positive DNR order, and this model was significant in elderly individuals and young adults.

It is possible that since younger adults are healthier or more independent premorbidly, and also have better outcomes following TBI when compared to older individuals, that discussions with physicians or patients' thoughts about the DNR order do not come up as frequently. Although young adults are rarely examined in regard to the DNR order, higher functional status and younger age have been associated with preference for CPR in US hospitals (Danis, Mutran & Fitzsimmons, 1991; Goodlin et al., 1999; Phillips, Wenger & Teno, 1996; Wenger et al., 1995). Furthermore, some research indicates that "ageism" plays a role in physicians' decisions to withhold CPR or to bring up discussions about DNR orders (Ebell, Doukas & Smith, 1991; Ebrahim, 2000; Hakim et al., 1996; Orenticher, 1989). The current findings indicate that even with increased transportation times, which can lead to an increased probability of secondary damage and fatal outcome (Bass, Gainer, & Carlini, 1999; Branas, MacKenzie, & ReVelle, 2000; MacKenzie et al., 2003), younger individuals do not have an increased probability of having a DNR order following TBI.

Greater DNR Orders and Fatalities in Rural Elderly Individuals

When geographic location and age were combined to predict outcome (examining Urban Elderly, Rural Elderly, and Rural Young Adults), significant effect sizes were only found when predicting fatalities and DNR orders and not when predicting injury severity, change in GCS scores from the scene of injury to trauma center admission, and transportation time.

The hypothesis that Rural Elderly individuals would be more likely to have a fatal injury compared to both Rural Young Adults and Urban Elderly individuals was not supported. Rural Elderly individuals only had a higher probability of a fatal injury when compared to Rural Young Adults. There were no significant differences between Rural and Urban Elderly individuals in regard to having a fatal injury. When DNR orders were examined, the hypothesis that Rural Elderly individuals were more likely to have a positive DNR order compared to both Urban Elderly individuals and Rural Young Adults was supported.

These results indicate that although elderly individuals tend to have higher fatality rates than younger individuals, the geographic location of the injury does not influence the likelihood of having a fatal injury. In regard to the DNR order, the results demonstrate that geographic location of the injury does matter. Elderly individuals that sustained injuries in rural areas were more likely to have a positive DNR order when compared to younger adults in the same area and elderly individuals in urban areas.

Previously cited work has established that rural areas lack support and rehabilitative services (Grossman, Kim, Macdonald, Klein, and Maier, 1997; Johnstone, Nossaman, Sckopp, Holmquist, & Ruprigkt, 2002). Some work has also indicated that rural communities do well with managing TBI in the acute stages, but have difficulties with resources for long-term rehabilitation and community reintegration services for residents following TBI (Sample, Tomter & Johns, 2007). It is possible that given the scarcity of support services available to individuals sustaining TBI, individuals may be more likely to have a DNR order in place due to a perceived lack of opportunities for recovery. However, further work is needed to understand if differences exist in the perceptions towards the DNR order in urban and rural communities because of differences in support services and long-term outcome.

Poorest Outcomes Following TBI in Older Elderly Rural Males

The final analysis in this study considered age, geographic location, and gender in order to determine which factors together were associated with: 1) the poorest outcomes based upon fatality rates and FIM scores, and 2) the most severe injuries following TBI. Overall, the Older Elderly Rural Male group had the least severe injuries, but the highest fatality rates and the lowest mean FIM scores at discharge. It was surprising that although the Older Elderly Males had the lowest FIM scores at discharge and also had high fatality rates, that they were not sustaining the most severe injuries in Pennsylvania. Instead, the most severe injuries were sustained by Urban Young Adults and intriguingly, this group had some of the highest FIM scores at discharge. Therefore, although the Young Adults in urban areas initially were having more severe injuries than older individuals, they were having better functional recoveries during hospital stay as evidenced by their higher functional statuses at the time of discharge. The finding that individuals higher in age tend to have worse functional outcome following injury, even with less severe injuries, has also been demonstrated in prior research (Mosenthal et al., 2002).

It was also interesting that, in contrast to the hypothesis that females would have the poorest outcomes, that the individuals identified with the poorest outcomes following TBI were males. As noted before, some work has shown that females tend to have poorer outcomes following TBI when compared to males; thus, it was expected that this would be true in older age as well. It is well established that in younger age groups, males are more likely to sustain TBI and have more severe injuries (Bruns & Hauser, 2003; Guerrero, Thurman & Sniezek, 2000; Jager et al., 2000; Kraus et al., 1994; Slewa-Younan, Green, Baguley, Gurka & Marosszeky, 2004) and results from the current study now show that males have poorer outcomes when sustaining TBI later in life as well.

In regard to fatalities, it is noteworthy that the two groups with the highest fatality rates were in rural injury locations. Previously cited work supports this finding, noting that rural counties/areas of low population density are related to increased fatality rates (Eberhardt et al., 2001; Muelleman et al.,1996; Maio et al., 1992). Some work has demonstrated that these higher fatality rates may be due to greater injury severity in rural areas (Chapital et al., 2007), but the findings from this study do not corroborate this.

One possible explanation for the higher fatality rates in rural areas could be the lack of access to healthcare services and proper insurance coverage available to individuals living in rural communities. This may inhibit individuals in rural areas from seeking out medical care when needed and could increase health problems in rural populations. For example, individuals in rural areas that are not adjacent to a metropolitan area are twice as likely to be underinsured when compared to urban areas (Ziller, Coburn & Yousefian, 2006). In addition, healthcare and insurance issues combined with older age may make the elderly in rural areas more susceptible to fatal injuries given worsened premorbid conditions. This issue is further complicated by the fact that not only is the elderly population increasing worldwide, but within rural areas 15% of residents are 65 years of age or older, which is 25% greater than estimates in the whole nation (United States Administration on Aging, 2010). Given the increasing elderly populations in both urban and rural areas, it is of utmost importance to target these populations in future prevention work in order to best help individuals in these areas be educated and aware of the causes and outcomes of TBI.

Study Limitations

This study is not without its limitations. While the current study provides observational information on epidemiological changes and also TBI outcomes, premorbid conditions were not examined. In this regard, factors that might contribute to epidemiological shifts and outcomes cannot be determined from the current study.

Also, as previously noted, these results do not include all TBI cases from 1992 to 2009 that occurred in the state. However, it is anticipated that these findings are representative of the TBI observed throughout the state and that no selection bias exists in the catchment in the trauma centers represented here that could account for the observed changes in elderly TBI incidence rates. Importantly, results from this study do not extend to individuals in older age groups sustaining mild TBI, and the trends and outcomes demonstrated in moderate to severe TBI in the current study may not represent other forms of brain injury.

It is important to note that data on DNR orders were obtained from medical charts and then coded in the PTOS; therefore, whether an individual had an order in place due to complications and poor prognosis from the injury itself or whether it resulted from other cultural, environmental, or premorbid medical history factors cannot be ascertained from the current results.

Another limitation of this study is that differences in geographic location were purely based on categorizations of county population density. This study does not take into account other important geographically dependent factors that may influence TBI outcomes such as cultural differences, individual perceptions to TBI outcomes, variations in educational resources, and differences in the availability and access to support services and rehabilitation centers. It will be useful to delve deeper into what specifically leads to differences in urban and rural injuries, and examine how differences in access to care and cultural attitudes towards injuries may influence outcomes following TBI (Corrigan & Bogner, 2008).

Future Directions

Given that the current study did not take into account mild traumatic brain injury cases in the state of Pennsylvania, and these injuries make up the majority of brain injury cases worldwide, it will be important to continue examining epidemiological shifts in TBI to determine whether the trends described in the current study can be extended to milder injuries.

In addition, given that elderly age, transportation time, and geographic location were all related to DNR orders, more work in this area would be helpful to fully understand these relationships. For example, other important factors that may need further consideration when examining DNR orders are the patient's medical condition (de Vos et al., 1998; Garcia, Romano, Chan, Kass & Robbins, 2000), the race/ethnicity of the patient (Callahan, 1988; Degenholtz, Arnold, Meisel & Lave, 2002; Kellogg & Ramos, 1995; Kiely, Mitchell & Marlow, 2001;

Shepardson et al., 1997), and whether the patient had spouses or caregivers during the time of illness/injury (Finucane & Denman, 1989; Meyers, Lurie, Breitenbucher & Waring, 1990). When examining geographic disparities in TBI, it will also be important to better understand what specific medical center, community, and individual factors within rural and urban areas may be contributing to differences in outcome given that cultural factors along with environmental barriers may be contributing to how individuals access trauma care and support services.

Furthermore, given the dramatic increases in elderly TBI, the increase in the proportion of OE TBI, and the poor outcomes found in the urban elderly male population, there is a need for greater outreach of awareness education and prevention work in areas that have greater populations of elderly males in rural areas. Elderly males in rural areas had the poorest outcomes in the current study, and more work examining how to best educate and protect this population is needed to help reduce detrimental outcomes following TBI.

Conclusions

The data from this study indicate that elderly TBI is on the rise in all subgroups, but that individuals in the OE group are at an elevated risk for TBI, fatal injuries, and low functional scores at discharge. Additionally, the OE group more frequently had a positive DNR order in place. Thus, results from this study indicate that increased age, regardless of geographic location and gender, can result in detrimental outcomes following TBI. This finding is most concerning given the dramatic increase in OE TBI over time, as well as the global growth of the elderly population.

This study also demonstrated that, although elderly age independently predicted TBI incidence rates and outcomes, the geographic location of the injury was also important to consider when examining fatalities and DNR orders. However, geographic location but did not prove to be a useful predictor of transportation time, injury severity, or change in injury severity scores during transport. Additionally, results from this study showed that over time, there were trends of decreased injury severity and transportation time in urban and rural areas.

When examining which demographic factors together predicted the poorest outcomes following TBI, the results demonstrated that Older Elderly Rural Males had the worst outcomes following TBI, when fatalities and functional scores at discharge were examined. The group that had the most severe injuries, but not the worst outcomes, included the Young Adults in urban areas. Given the differences in TBI outcome and epidemiology established in this study when considering age, geographic location, and gender, prevention and awareness work should be tailored to the demographic group being targeted in order to provide the best educational resources.

Due to the increase in OE TBI and the poor outcomes in Older Elderly Rural Males, it is imperative to target TBI education and awareness in the elderly. Statewide awareness of TBI risk factors for falls in the elderly must increase in order to prevent injuries. Research compiled by the Center for Disease Control and Prevention (CDC, 2008) provides recommendations for community-based fall prevention methods and interventions that could be useful for elderly individuals who are at risk for sustaining injuries. Efforts such as more community physical activities targeted at the elderly, more structures to community buildings to prevent falls (i.e. guardrails), as well as work targeting the other common causes of TBI in the elderly (i.e. reminding individuals about the importance of automobile safety and having courses to update elderly individuals on driving skills) might be beneficial to implement in communities with greater elderly populations. Additionally, making sure elderly individuals routinely have hearing and vision checks may also help prevent injuries (Ferrel & Tanev, 2002). It would be useful for communities to work together to provide education and awareness to individuals, and also for health care providers to routinely provide patient education in order to increase awareness of the risks of falls and how to prevent falls. Health care providers must work together with patients to examine physical mobility, vision, and also medication management to help reduce preventable falls.

Current TBI funding and outreach work in Pennsylvania is focused on preventing and managing concussions in the youth, and providing support services to survivors of brain injury. However, funding and outreach is not being focused on educating individuals and health care providers on strategies to prevent TBI in their communities. More specifically, Pennsylvania Act 101 (The Safety in Youth Sports Act) was established to create standards for managing concussions and traumatic brain injuries for student athletes. The intention of the law is to protect youth athletic participants and educate athletes, parents, and staff on the dangers of concussions and head injuries. Also, the Pennsylvania Head Injury Program (HIP) created in 1988 helps pay for head injury rehabilitation services for people who qualify in order to promote independent living. No current funding or state policy is in place that focuses on prevention and education of elderly TBI in Pennsylvania. Importantly, there are federal programs available for states to obtain assistance in dealing with TBI prevention and outcomes. For example, the TBI Act programs administered by the US Department of Health and Human Services through the CDC provide grants to states for prevention activities and public education. Additionally, the Health Resources Services Administration Federal TBI Grant Program provides funding for expanding and enhancing service delivery. These resources may be beneficial in providing state-wide funding that can be used in targeting prevention and awareness programs for the elderly in various communities in Pennsylvania.

Currently, given the rise of elderly TBI, there is a need for more state funded services and cost-effective prevention and education programs focused in elderly communities. Concerted efforts from health care professionals and community members, along with law enforcement efforts to reduce MVA accidents within all age groups, must be implemented to reduce the incidence of TBI. These efforts can help raise TBI awareness and education and ultimately reduce the likelihood of detrimental outcomes and disability in the elderly.

APPENDIX A

Urban and Rural Designations for Pennsylvania Counties

County	Population Density	Urban or Rural
Adams	196	Rural
Allegheny	1676	Urban
Armstrong	106	Rural
Beaver	392	Urban
Bedford	49	Rural
Berks	480	Urban
Blair	242	Rural
Bradford	55	Rural
Bucks	1035	Urban
Butler	233	Rural
Cambria	209	Rural
Cameron	13	Rural
Carbon	171	Rural
Centre	139	Rural
Chester	665	Rural
Clarion	67	Rural
Clearfield	71	Rural
Clinton	44	Rural
Columbia	139	Rural
Crawford	88	Rural
Cumberland	432	Urban
Dauphin	511	Urban
Delaware	3041	Urban
Elk	39	Rural
Erie	351	Urban
Fayette	173	Rural
Forest	18	Rural
Franklin	194	Rural
Fulton	34	Rural
Greene	67	Rural
Huntingdon	52	Rural
Indiana	107	Rural
Jefferson	69	Rural
Juniata	63	Rural
Lackawanna	467	Rural
Lancaster	550	Urban
Lawrence	254	Rural
Lebanon	369	Urban
Lehigh	1013	Urban
Luzerne	360	Urban
Lycoming	95	Rural
McKean	44	Rural

Mercer	173	Rural
Mifflin	114	Rural
Monroe	279	Urban
Montgomery	1656	Urban
Montour	140	Rural
Northampton	805	Urban
Northumberland	206	Rural
Perry	83	Rural
Philadelphia	11379	Urban
Pike	105	Rural
Potter	16	Rural
Schuylkill	190	Rural
Snyder	121	Rural
Somerset	72	Rural
Sullivan	14	Rural
Susquehanna	53	Rural
Tioga	37	Rural
Union	142	Rural
Venango	82	Rural
Warren	47	Rural
Washington	243	Rural
Wayne	73	Rural
Westmoreland	355	Urban
Wyoming	71	Rural
York	481	Urban

APPENDIX B

Subscales and Scoring for the Glasgow Coma Scale

Eye Opening:

4 = Spontaneous

3 = To voice

2 = To pain

1 = None

Verbal Response:

5 = Oriented

4 = Confused

3 = Inappropriate words

2 = Incomprehensible sounds

1 = No verbal response

Motor Response:

6 = Obeys command

5 = Localizes pain

4 = Withdraws

3 = Flexion response

2 = Extension response

1 = No motor response

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SELECT HONORS AND AWARDS

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2010-2011	Donald A. Trumbo Psychology Department Student Research Fund, The Pennsylvania State University Travel Award.
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2008	Diversity Research Funding Award, The Pennsylvania State University

SELECT PUBLICATIONS

Ramanathan, D.M., McWilliams, N., Schatz, P., & Hillary, F.G. (2012). Epidemiological shifts in elderly TBI: 18-year trends in Pennsylvania. *Journal of Neurotrauma. 29,* 1371-1378.

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